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OF THE
INTERNATIONAL SYMPOSIUM ON MARINE POLLUTION RESEARCH

JANUARY 27-29, 1976
Gulf Breeze, Florida

Samuel P. Meyers
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana

Sponsored By
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ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
GULF BREEZE, FLORIDA 32561

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16. ABSTRACT

Symposium papers discuss how man's activities have affected natural resources of a coastal environment. Participants, representing international aspects of coastal pollution, reviewed current status of research and procedures planned to minimize offshore coastal damage. Subjects included: "An Overview of the USEPA Program in Marine Pollution Research", Carl R. Gerber; "Responsibilities for Marine Pollution Research Within Federal Agencies of the United States," Norman L. Richards; "Overview of Marine Pollution Research in the Baltic," K. Rozdzynski, "Marine Pollution Research in Yugoslavia: An Overview," V. Pravdic; "Overview of Marine Pollution Research in Egypt," Saad El-Wakeel; "Overview on Pollution in the Coastal Environment of Pakistan and its Possible Implication for the Marine Ecosystem," S. M. Haq; "Overviews on Marine Pollution in India," K Ranga Rao; "Research Needs Concerning Pollution of the Marine Benthos," R. C. Swartz; "Hydrological, Chemical and Physical Processes Affecting Pollution of the Baltic Sea," A. Trzosinska; "Investigation of Pollution-Stressed Littoral Communities in the Northern Adriatic," D. Zavodnik; "Microbiology and Chemistry of Estuarine Surface Microlayers," A. W. Bourquin and D. G. Ahearn; "Survival of Viruses in the Marine Environment," George E. Schaiberger, Charles P. Gerba and Enrique G. Esteves; "Relationship of Marine Pollution to Human Health," Ronald Engle; "Bioassays as Indicators of Pollution Effects," David L. Coppage.

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OPENING REMARKS

John D. Costlow
Director, Duke University Marine Laboratory
Beaufort, North Carolina 28516

The purpose of this meeting is extremely straightforward. It is to discuss the extent to which by-products of man's activities, including those from industrial efforts, agricultural efforts, and the related concentration of large numbers of people in coastal areas, are having a deleterious effect on the natural resources of the coastal environment, i.e., the problem of marine pollution. It is especially significant that this meeting represents a truly international gathering of scientists because coastal pollution is a problem common to all nations bordering on the sea.

Over the past five years there have been a number of expressions of concern at many levels of government. Through several international conventions we have seen regulations dealing with the discharge of petroleum products from vessels at sea and further regulations concerning the dumping of waste materials in the oceans. Although these conventions and regulations have served a number of valuable functions, including the proper focus on the problems themselves, I believe we would agree that focus in itself is not sufficient. For the scientific community there remains the rather awesome task of developing an overall program of research on specific aspects of marine pollution, ideally designed to provide the basic information from which regulatory agencies, both national and international, can develop a sound basis for the intelligent control of those activities of man which cause pollution. In addition to providing the background for government regulatory needs, it has also fallen to the scientific community to provide data and guidance to representatives of both industry and the government and assist them in developing planning procedures which would minimise future pollution within the coastal area.

It should be obvious, and it is certainly reflected at this symposium, that coastal and marine pollution is a truly international problem rather than one which is restricted to any one country or area of the world. I am especially pleased to have the opportunity to participate in this symposium because I have had the privilege of visiting a number of the institutions represented here and I feel somewhat familiar with the coastal problems facing a number of countries throughout the world. In visiting some of you over the past few years I have seen, in varying stages of completion, examples of very impressive industrial development; awesome efforts to reclaim land from the sea, sizable complexes for the generation of energy for new industry, clearing of vast expanses of forested land for agriculture, competition for ground water by expanding industries, problems of runoff from agricultural areas and the potential for catastrophic effects of accompanying nutrients and pesticides on areas important to commercial fisheries, and numerous examples of poisoning of adjacent waters, including the flora and fauna, by certain highly toxic by-products of industry. I believe we would agree that no one, in the two remaining decades of the twentieth century, can honestly speak in terms of "stopping" development. We should, however, by providing accurate information on the effects and projected costs to the environment, be able to exert some degree of intelligent control over the direction of development and encourage it along the lines of "multiple use" of limited natural resources. This can only be achieved through a basic understanding of the coastal environments themselves, coupled with proper planning and a more efficient use of these natural areas.

During the next few days we will be involved in discussions of marine pollution research activities in a variety of areas around the world, including the Baltic, the Adriatic, the Mediterranean, the Arabian Sea, and the Indian Ocean. I personally am looking forward to having the opportunity to discuss specific research activities in many of these areas and compare them to our own efforts here in the United States. One of the main objectives of this meeting will be to provide a firm basis for a broader understanding of marine pollution research activities on an international scale and, it is hoped, lay the groundwork for far more intensive cooperative research between and among the countries which are represented here, all ultimately aimed at a more objective use and efficient protection of the coastal and marine environments.

AN OVERVIEW OF THE USEPA PROGRAM IN MARINE POLLUTION RESEARCH

Carl R. Gerber
U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C.

I am pleased to be here today and to have this opportunity to address such a distinguished group of marine scientists. Though I am not a marine scientist or a marine pollution expert, I have a keen interest in the problems which face us in ensuring the environmental quality of the world's oceans. An essential starting point in solving these problems is to agree on the needs for and types of research which are desirable or necessary and to work toward them on a coordinated international basis.

The life of the oceans historically has been relied upon as a major source of man's food. In the more recent era, we have begun to recognize the oceans as potential sources of man's food. In the more recent era, we have begun to recognize the oceans as potential sources of minerals and petroleum as well. As land-based resources have become more scarce, there has been a movement in all parts of the world to seek new sources of supply from, and from under, the seas. New technologies have made exploitation not only a possibility, but an attractive and profitable reality.

Although major developments are probably still years away, we need to start thinking now about the global effects of our actions. By planning ahead, we should be able to take advantage of the economics of building environmental protection into technologies as they develop, rather than relying upon the retrofit solution to which we have too frequently turned in the past.

Another, and probably greater, threat to the oceans arises not from exploitation of their internal resources, but from the use of the seas as a sink for mankind's wastes. Wastes enter the ocean basically in three ways--from rivers, from the atmosphere, and from direct dumping activity. Evidence points to the fact that the ocean cannot break down certain of these wastes, and that these nondegradable pollutants are accumulating in the marine environment.

Any regulations or controls which the world may choose to employ to protect the oceans must be based on a sound knowledge of the effects of pollutants on marine ecosystems, which in turn must have as a foundation full information on how marine systems work.

Because the waters of the earth know no boundaries, the problem of marine pollution is necessarily global in scope. Tides, currents, atmosphere/ocean interactions and the impact of shipping make marine pollution an international dilemma which will require an international solution. In mounting such an effort, there is a need for identifying proper roles for the many (as many as 114) multinational organizations which deal with the oceans.

We must also recognize that different ecosystems have similarities and that conclusions of research can often be translated from one ecosystem to another. It is to all of our benefits, if each nation conducts the work basic to its needs in a coordinated manner. This will avoid duplication and waste of the scarce resources which are available to study the problems.

The United States Environmental Protection Agency is in the process of evaluating its research activities. Although most of our work will continue to be done in support of legislative mandates, we also hope to devote some resources to more general studies. As the tools are becoming available, we are seeing, more and more, the need to look at problems on a broad scope. One area of effort is to develop ecosystem models that can test and explain the effects of different classes of pollutants. This is the approach we must take if we are ever to get ahead in the control and abatement of pollution. We also need an integrated understanding so that we can make the necessary trade-offs between use and protection of ocean resources.

We are fortunate to have with us experts from each of EPA's laboratories which conducts marine research. In a moment, these representatives of our laboratories in Corvallis, Oregon; Narragansett, Rhode Island; and here at Gulf Breeze, Florida, will explain the roles of their facilities in conducting marine research and the focus of their work as it relates to the global marine problem. Subsequently, Dr. Norman Richards will discuss other United States research which is being conducted outside of EPA.

In closing, I would like to lay out some areas I would hope this symposium will address.

(1) There are specific problems that each of us face, and we should outline the plans we have for investigating such problems;

(2) Upon gaining a clearer understanding of the ongoing work in each country, we will develop a more general view of the state-of-the-art of work underway throughout the world;

(3) We should conduct a thorough discussion of the entire field of marine research to better understand broad common problem areas which we can investigate, or modify ongoing work to address;

(4) We should reach a consensus on the need for monitoring and collection of baseline data in a comprehensive manner, as this is a means of observing, over time, emerging trends in the effects of marine pollution;

(5) We should discuss compatible approaches to our studies so that our investigations may fit together to address the global problems; and

(6) We should discuss in detail and agree on follow-up action on data collection and exchange of research results.

In summary, I hope that this meeting can begin the process whereby those of us here can plan and coordinate activities so that duplication is avoided and that each of our projects can contribute to advancing the state of knowledge on marine pollution.

If we can leave this symposium with an understanding of our collective needs, the best methods to satisfy them, and a sense of the individual roles that each country will play in developing a coordinated international effort, then we are a good deal closer to ensuring the environmental quality of the oceans.

RESPONSIBILITIES FOR MARINE POLLUTION RESEARCH WITHIN FEDERAL AGENCIES OF THE UNITED STATES

Norman L. Richards
U.S. Environmental Protection Agency
Environmental Research Laboratory
Gulf Breeze, Florida 32561

I am delighted to see so many countries represented at this meeting as testimony to the concern we share for the effects of pollution on the marine environment. As scientists and managers of marine pollution research, we have an auspicious opportunity to informally discuss our national research needs, approaches, and aspirations in an effort to define areas of common interest. I hope that this symposium will result in collaborative research projects and exchange of research results, techniques, and philosophies.

Technical papers to be presented from the United States will review specific projects, techniques, and research problem areas. My talk is concerned with:

(1) Geography and human population in the United States: the flow patterns of major oceans, rivers, and currents along the 100,000 miles of United States coastline; and the distribution of human population along the coastal zone.
(2) An example of how federal agencies interact: the role of federal agencies which have major responsibilities in Outer Continental Shelf exploration and development of offshore oil and gas reserves.

Geographical Characteristics

A schematic representation of the flow of the major rivers of the United States is given in Figure 1. It shows that the Mississippi River carries the largest quantity of water of any river in the United States and drains approximately two-thirds of the continental United States. Its flow into the Gulf of Mexico amounts to approximately 620,000 cubic feet of water daily. The major contributors to this flow are the Missouri River, which originates in the Rocky Mountains in the State of Montana, and the Ohio River, whose flow commences in Pennsylvania. From the standpoint of flow, the Columbia River is a secondary stream due to a lower volume of discharge at the coastline. On the eastern seaboard, the Potomac and Susquehanna River empty into the Chesapeake Bay, an important estuary for fisheries resources.

The distribution of population near the coastal zone of the United States is shown in Figure 2. (The population density of the interior is not illustrated; each dot represents approximately 10,000 persons.) In analysing population centers, a definite relationship emerges between the total and the availability of water. The density of population in the coastal zone of the eastern half of the country can be explained partly by the availability of water in the East, while the lack of rainfall restricts most agriculture to irrigated valleys in the western United States. A plentiful water supply encouraged eastern urban and industrial growth and fostered development of small and intensively cultivated farms. With the possible exception of the Pacific Northwest, western metropolicenters are required to develop water sources in distant areas less deficient in moisture. In contrast to the eastern United States, large regional cities are not as numerous in the West and generally are located in the irrigated belts.

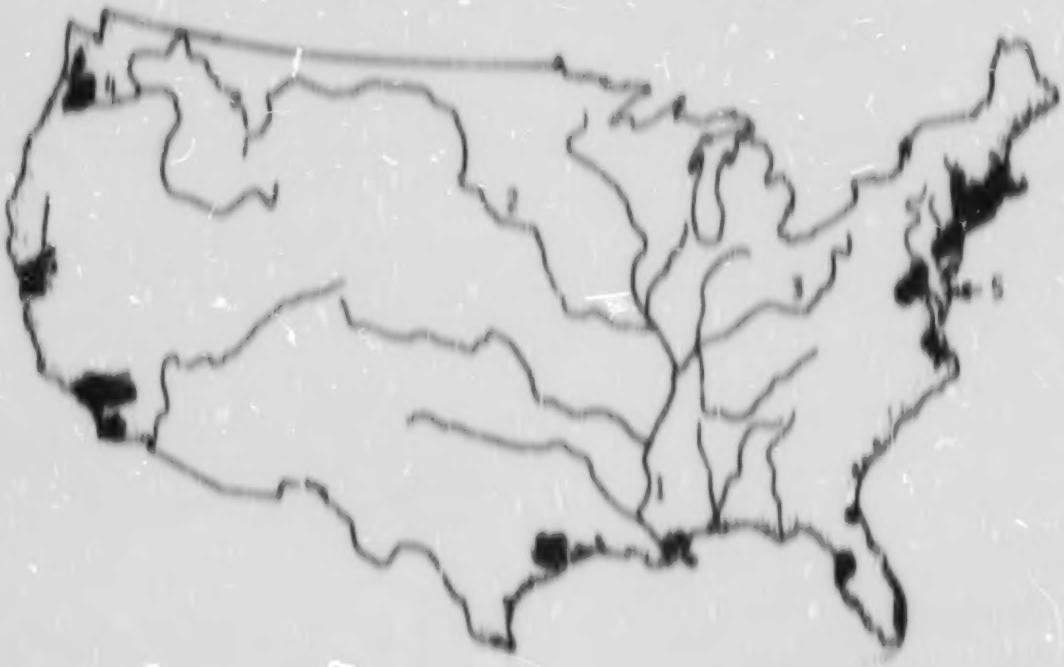

Figure 1. Major rivers and distribution of human population along the coastal zone of the United States. 1--Mississippi River, 2--Missouri River, 3--Ohio River, 4--Columbia River, 5--Chesapeake Bay. Shaded areas denote dense population.

Figure 2 illustrates the flow of major summer surface currents along the United States shoreline. The Gulf Stream, a warm current originating in the Gulf of Mexico, moves northward in a warming sweep in its route along the eastern Atlantic Coast. In contrast, currents originating in the Sea of Japan bathe the western United States coastline with cold water in their southward flow in the Pacific Ocean. The Gulf of Mexico is a relatively independent basin with unusual daily tides.

Federal Agencies Involved in Offshore Oil Development

Now that I have given a cursory overview of the characteristics of the coastal zone of the United States, I would like to discuss how federal agencies interact even though they have different legislative mandates. I will do this using a timely example: marine and estuarine effects of Outer Continental Shelf (OCS) development for petroleum and natural gas.

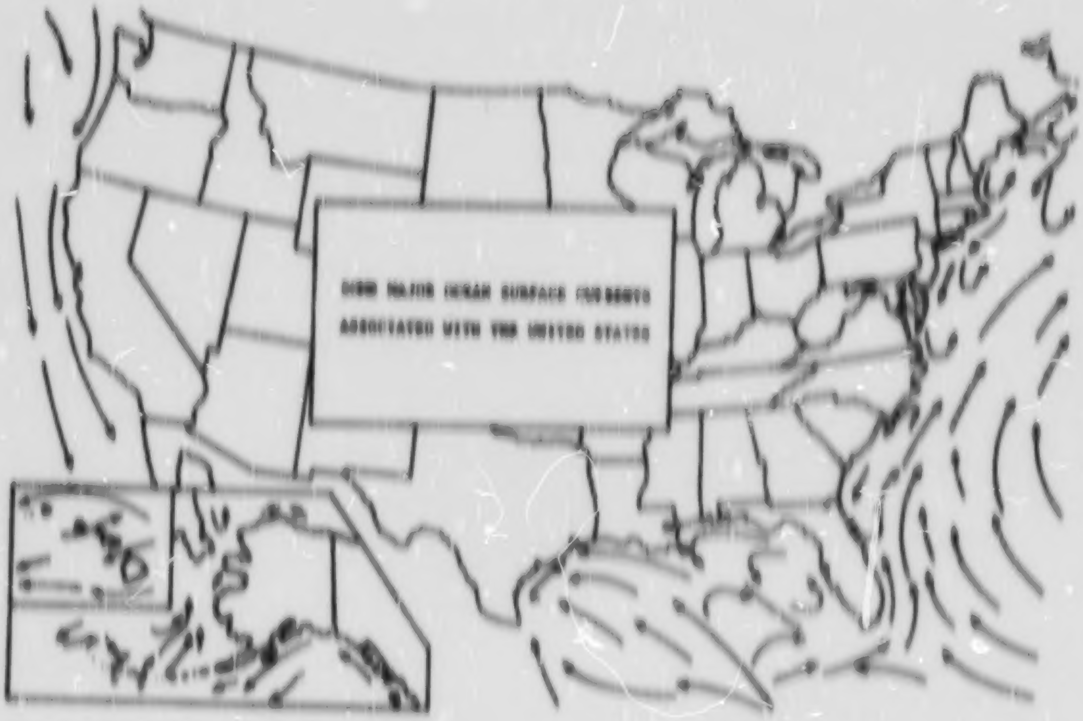
SOME MAJOR OCEAN SURFACE CURRENTS
ASSOCIATED WITH THE UNITED STATES

Figure 2. Flow of major summer surface currents along the United States shoreline.

In the United States, marine science activities and oceanic affairs are conducted by 21 organizations in six departments and five agencies (Council on Environmental Quality, 1974). An effort is underway to establish a comprehensive national program focused on the vital role of the oceans in the nation's welfare, economic self-sufficiency, and national security.

Several federal organizations concerned with environmental management and control are adversary bodies empowered to enforce regulatory decisions aimed at protecting man and aquatic life in marine, coastal, and estuarine environments. The U.S. Department of Interior's Bureau of Land Management, for example, administers an OCS Environmental Studies Program which is designed to gather information for decisions regarding offshore oil exploration. OCS Environmental Studies are based on three elements: (a) baseline studies describing existing conditions; (b) long-term monitoring studies; (c) special investigations analyzing the marine environmental impact of increased oil production. A primary concern is the effect of oil development (extraction, transportation, and conversion) on aquatic communities and human activities.

Research on effects of offshore development is conducted by the Energy Research and Development Administration, Department of Health, Education and Welfare, Department of Commerce, Department of Interior, National Science Foundation, Environmental Protection Agency, Federal Energy Administration, and other organizations that provide data for offshore development impact assessment. An interagency working group has developed a five-year research plan on health and environmental effects of energy use which supports a portion of this research (Parker, 1974). Other research funding has been made available by the Bureau of Land Management, certain states, and individual federal agencies.

The Environmental Protection Agency is particularly concerned with potential damage to the coastal zone and other effects of OCS oil exploration, extraction, transportation, conversion and end use. Ideally, offshore oil fields should be developed where there is a relatively low environmental risk and proven technology for environmentally safe exploration and development. Joint planning should be done by national, state, and local organizations. State governments should be made cognizant of the onshore effects of offshore development such as refineries, pipelines, etc.

The global problem of industrial and energy development commensurate with sound environmental practices is one we all share. I would like to illustrate the interwoven roles of United States agencies in seeking solutions to two major questions: How can oil be obtained from its OCS with only minimum degradation to the marine estuarine and onshore environment? What research needs to be done on the effects of OCS development?

Leasing, exploration, and development of OCS oil fields have high priority as a national goal. Figure 3 illustrates the general areas which have been proposed for development by the U.S. Department of Interior's Bureau of Land Management. It should be noted that the areas are very extensive and include environmental extremes ranging from the Arctic to the subtropics, with dramatically different marine biota.

Environmental groups and states have demanded a rigorous scrutiny of the potential effects of proposed leasing for oil exploration in the coastal zone ecosystem. As a result, newly enacted environmental laws have modified the plan to lease systematically a predetermined number of acres each year. These laws were enacted to ensure adequate safeguards against any adverse impacts of development on the estuarine marine resources, human health, and onshore impacts of offshore development.

The process allowing private firms to purchase offshore leases involves a sequence of activities. Following a preliminary environmental impact assessment, tracts are offered for sale by the Bureau of Land Management. A solicitation of nominations are accepted whereby industries can express interest in a tract, and environmental groups, states, etc., can register objections (negative nominations). A draft environmental impact statement is then offered to federal agencies for comment. For example, the National Marine Fisheries Center of the U.S. Department of Commerce can comment on marine resources. The Geological Survey may comment on seismic activity; the Fish and Wildlife Service on rare and endangered seabirds; state governments on potential effects of development on resources or potential onshore impacts, and so on.

After 90 days, comments are incorporated into a final Environmental Impact Statement. In some instances, tracts were not leased after the Environmental Protection Agency rated proposed drilling areas as environmentally unsatisfactory for development and referred its assessment to the President's Council on Environmental Quality.

Following public hearings, the decision to lease for exploration and for ultimate development is rendered. Tracts which are leased for exploration may ultimately be developed for production. If this occurs, oil companies are required to comply with specific operating orders that are monitored and enforced by the U.S. Geological Survey.

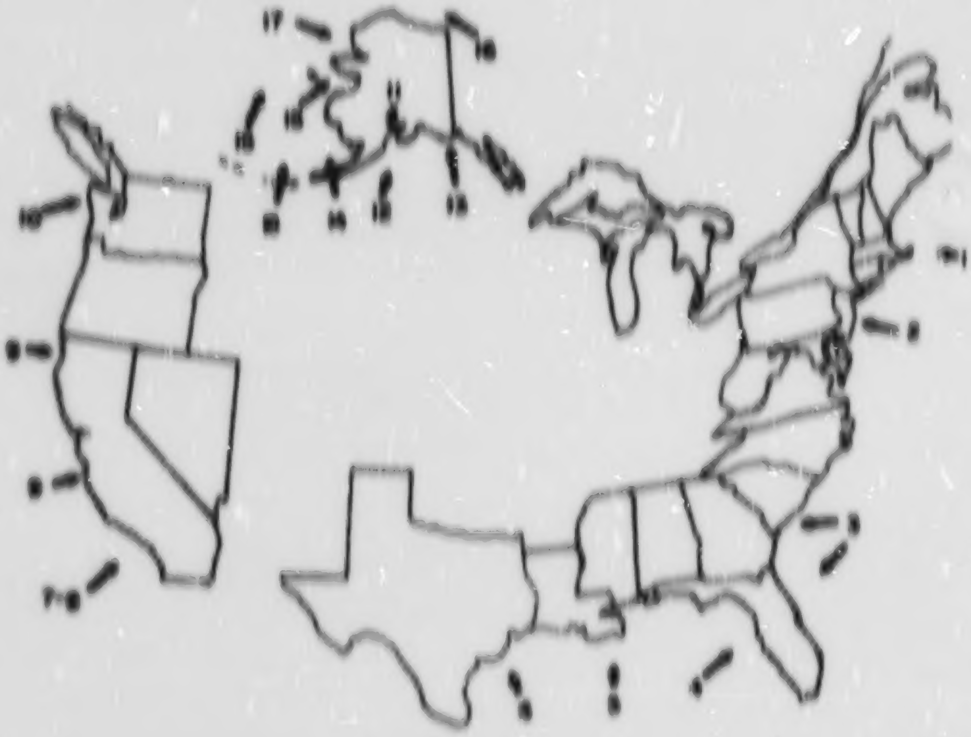

Figure 3. Tracts proposed for oil and gas exploration and development. Key: Atlantic Coast--(1) North Atlantic, (2) Mid-Atlantic, (3) South Atlantic and Blake Plateau. Gulf of Mexico--(4) East Gulf, (5) Central Gulf, (6) West Gulf. Pacific--(7) Southern California Borderland, (8) Santa Barbara, (9) North and Central California, (10) Washington-Oregon. Alaska--(11) Cook Inlet (State-Federal), (12) Southern Aleutian Shelf, (13) Gulf of Alaska, (14) Bristol Bay, (15) Bering Sea Shelf, (16) Beaufort Sea, (17) Chukchi Sea.

Interaction of U.S. Agencies in Environmental Management

As part of the International Decade on Ocean Exploration, the National Science Foundation sponsored a conference (Parker, 1974) to study the possibility that chemical pollutants in the marine environment could adversely affect marine life. A subsequent workshop concerned with petroleum in the marine environment was held under the auspices of the Ocean Affairs Board of the National Academy of Sciences (U.S. General Accounting Office, 1975).

In another coordinated effort, the Interagency Working Group on Health and Environmental Effects of Energy Use (Wilson, 1975) proposed a five-year research program on marine and estuarine ecosystems impacted by energy development.

The program is now being implemented by the Energy Research and Development Administration (ERDA), the National Oceanic and Atmospheric Administration (NOAA), the Fish and Wildlife Services (FWS), and the Environmental Protection Agency (EPA). Some of the major projects are:

(1) Summarize and analyze historical data on marine and estuarine ecosystem.
(2) Study the variability of marine and estuarine environmental conditions.
(3) Monitor locations subject to energy-related development.
(4) Determine immediate and long-term effects of critical pollutants (metals, temperature, petroleum hydrocarbons, radionuclides, antifouling biocides, and drilling muds) on selected organisms and ecosystems.
(5) Study effects of oil and gas structures on marine pollution and communities.
(6) Develop and use models to predict the impact of energy-related activities on priority marine and estuarine environments.

The National Science Foundation Conference (Parker, 1974) recommended:

(1) that biological effects of chemical pollutants be investigated using biota from the continental shelf and open sea;
(2) that acute toxicity tests be undertaken using representative species or organisms from phytoplankton of the open ocean and coastal areas, fish of the continental shelf, marine crustacea (crab, shrimp, amphipods, and mysids), mollusks, and echinoderms;
(3) that increased effort be directed toward two problems areas: (a) laboratory cultivation of open ocean marine plants and animals, and (b) development of improved physiological and biochemical parameters for detecting biological effects;
(4) that chemical projects focus on the characterization of petroleum toxins; and
(5) that studies involving geochemical transport, accumulation and retention be undertaken for selected pollutants.

OCS development research is an example of how United States agencies with different legislative mandates can be rallied in support of a priority research goal. I have attempted to illustrate how government research agencies responded to a crucial problem related to environmental decision-making. In the process, I have attempted to give you an overview of some important problems currently under investigation in our attempt to understand the potential impact of oil exploration. Other speakers from the United States will discuss specific estuarine and marine research programs of the U.S. Environmental Protection Agency and other related topics.

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OVERVIEW OF MARINE POLLUTION RESEARCH IN THE BALTIC

Kazimierz Różdżyński
Institute of Meteorology and Water Management
Sea Department
Gdynia, Poland

The Baltic Sea is an inland shelf sea of northern Europe and a part of the Atlantic Ocean, connected with the latter through the Danish Sounds and the North Sea. The area of the Baltic, together with the Danish Sounds, amounts to 415,125 km^2 and the volume (mean depth 52 m, maximum depth 459 m) is 21,714 km^3. The Baltic has a meridional span of 1,500 km and an equatorial span of 650 km, and is built up of 3 basins--Bornholm, Gotland, Bothnian basin, and the Sounds.

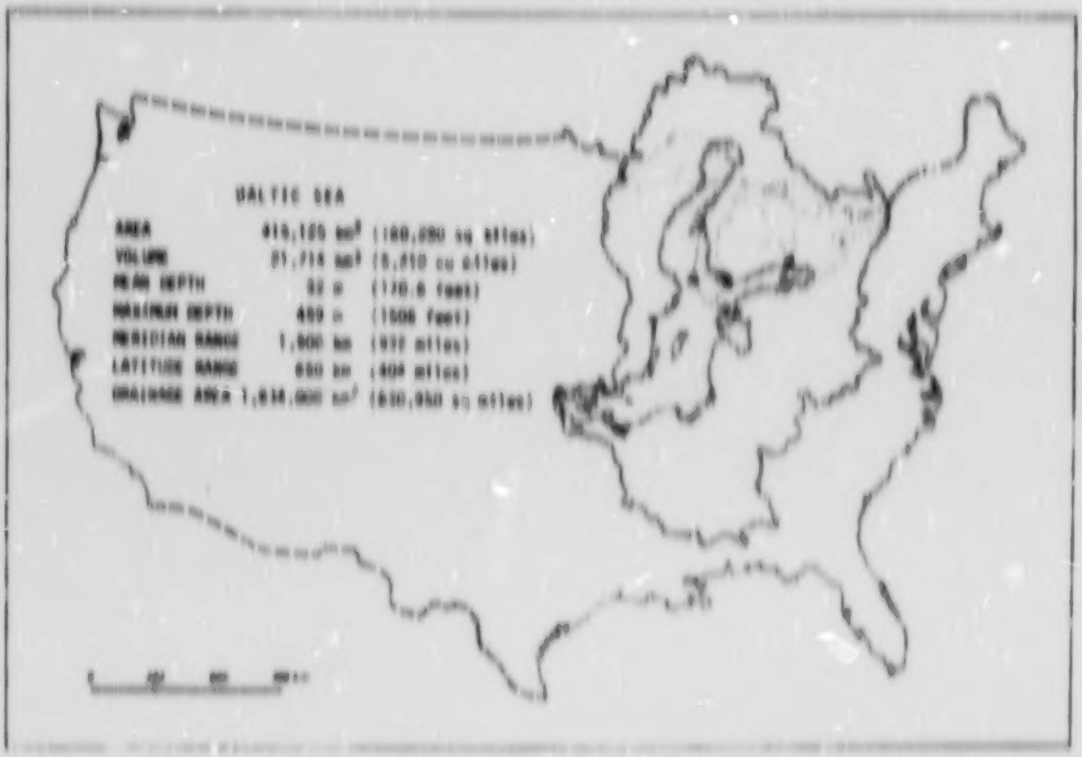
BALTIC SEA
AREA 415,125 km² (160,280 sq miles)
VOLUME 21,714 km³ (5,210 cu miles)
MEAN DEPTH 52 m (170.6 feet)
MAXIMUM DEPTH 459 m (1506 feet)
MERIDIAN RANGE 1,500 km (932 miles)
LATITUDE RANGE 650 km (404 miles)
DRAINAGE AREA 1,634,000 km² (630,950 sq miles)

Figure 1. Characteristics of the Baltic Sea (map superimposed on map of the United States).

The annual surface water temperature varies greatly, in August reaching 18-20 C in the northeast and 12-14 C in the north; in February it falls to 2.5 C in the non-freezing part of the Gotland Basin and 1 C in the southeastern part. The temperature of deep water is related to salinity and water density stratification. Two water layers can be distinguished here, the upper containing brackish waters (river inflow and rainfall) of lesser density and the lower layer with 2-3 times greater salinity and density (inflows of saline oceanic waters through the Sounds). Lowest temperatures, around 2 C, are maintained in the lower part of the upper layer at a depth of 60 m, increasing from that point in either direction, i.e., to the surface and bottom, reaching 5 C at the bottom. This temperature corresponds to the lowest autumn-winter temperatures of surface waters in the North Sea, which enter in the form of inflows to the Baltic due to heavy western storms.

Salinity in the Baltic depends on inflow of saline waters from the North Sea, and varies in the upper layer from 10 ppt in the southeast to 2 ppt in the north; in the deep-water layer salinity ranges from 20 ppt in the southwest to about 12 ppt in the Gotland Basin.

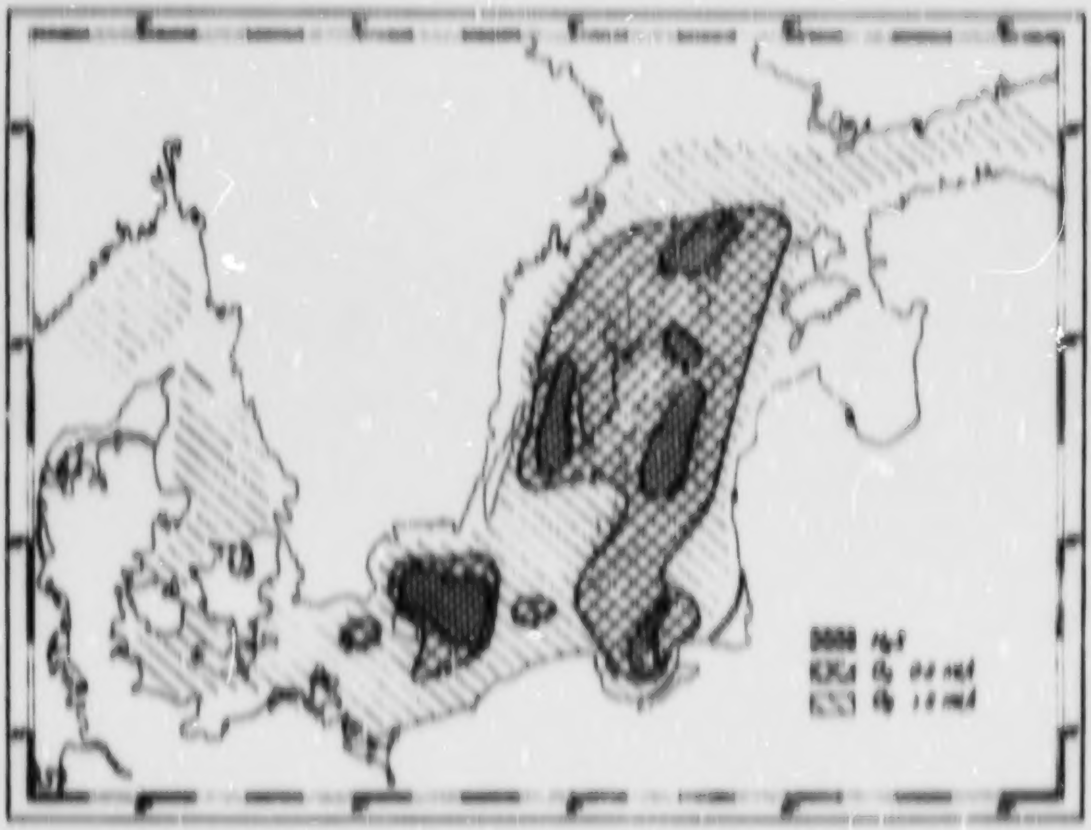

Figure 2. Approximate distribution of oxygen and hydrogen sulfide in the deep-water layer of the Baltic Sea, September-October 1975.

Currents are of variable character. From the north along the Swedish coast a constant surface current leads out fresh Baltic waters into the North Sea. On the other side along the Polish coast there generally appears a current directed to the northeast, generated by prevailing western winds, and building up shallows, flats and sand bars. From the Atlantic bottom inflows occur bringing saline waters easterly along the coast. Ecologically, the Baltic is a transient and poorly equipped sea environment, where biological life is concerned. Both saline and freshwater plants and sea organisms are represented here.

The above-mentioned and encyclopedic hydrological data on the Baltic do not suggest any need for wide-range studies of the sea; however, it should be remembered that almost 75 rivers enter the sea, bringing about 433 km^3 of fresh water from a drainage area of 1,634,000 km^2 which is inhabited by over 140 million people in six Baltic countries. This territory is one of the most populated world areas, with high urban development (60 large towns), highly developed industry (15% of world production), and intensive agriculture, farming and forestry administration. Thus, a statement that the previous process of contamination for this basin, in which total water exchange takes around 30 years, is exceptionally dangerous and merely rhetorical.

The Baltic Sea also has great importance for communication and trade for all Baltic countries, since it joins them with the open Atlantic routes. A modest picture of sea traffic intensity shows 70,000 merchant ships passing across the Kiel canal every year and nearly 20 million passengers crossing the Danish Sounds annually, not even taking into account the fishing fleet which numbers in tens of thousands.

The planned rapid development of human activity in the Baltic area, the anticipated simultaneous industrial and urban development of the coastal area, the evolution of an offshore industry, growth of recreational needs and facilities as well as adaptation of special water areas for maricultural purposes, all serve to heighten the problem of environmental protection of this area.

Regarding protection and evaluation of the Baltic Sea area as a task to be effectively realized only through common effort of all Baltic countries, Poland took the initiative to organize a Diplomatic Conference of Baltic countries. The Conference took place at Gdańsk in September 1973 and its outcome was the signing by all participating countries of the Convention on Fishing and Conservation of Living Resources in the Baltic Sea and the Belts. This act of international law was presented as precedent in the United Nations forum. In further steps, the Baltic countries conducted a diplomatic conference concerned with the protection of the Baltic Sea environment (Helsinki, March 18-23, 1974); participating were Denmark, Finland, East and West Germany, Poland, Sweden and the Union of Soviet Socialist Republics. The representatives decided to undertake individually and jointly the relevant legislative, administrative, and other adequate means to prevent and reduce pollution, thus protecting and enriching the environment of the Baltic Sea area and territorial waters.

Pollution in the act mentioned was defined as introduction by human beings, directly or indirectly into the sea environment, of any sort of substance or energy causing harmful effects, encompassing danger to human health, peril for all species living in the sea, hindrance of proper exploitation of the sea (including fishing), reduction of water utilization, and aesthetics of the sea. The list of dangerous substances includes DDT with its derivatives and PCB. Successive counteractions were undertaken aiming at total elimination of these two substances and expressed as the banning of any transport or trade, service and application of products containing the materials concerned. Plans call for further means of control and minimalization of any dangerous land effluents brought to the sea, i.e., mercury, cadmium and their compounds, other metals, phenols, cyanide, various hydrocarbons, toxic organic silicon compounds, permanent pesticides, radioactive materials, oil and petroleum wastes, and the like.

Upon completion of the recommended Convention safeguards, the Interim Commission, with a scientific Technological Working Group, engaged in working out a program in which the following directions are considered:

Task 1--Quantity of pollution brought into the Convention area

Task 2--Methods and techniques of measurement and control of pollution

Task 3--Distribution of pollution in the Baltic Sea area including the littoral zone

Task 4--Transport and spread of pollution in the sea

Task 5--The effect of pollution on living organisms

Task 6--The degree of pollution and its consequences, risks and reversibility

Task 7--Elimination of pollution in the sea environment

Task 8--Technical methods to prevent the introduction of pollution to the sea

Task 9--Introduction of standards describing the permissible amount of pollution brought into the sea.

A second international forum concerning wide-ranging sea pollution problems which included the Baltic basin is the International Council of Exploration of the Sea (ICES). Within the framework of ICES the following organizations are acting:

a) Advisory Committees on Marine Pollution, with chairmen of different committees taking part as well as leaders of Working Groups, their interests covering the sea pollution problem.

b) ICES/SCOR Working Group on the Study of Pollution of the Baltic and Its Effects on Living Resources. This Group took a seven-point action program (published in Cooperative Research Reports No. 42, ICES, 1974) covering the total range of pollution problems in the Baltic Sea. These include:

Task 1--Water exchange and dissolved material, between the Baltic and North Seas
Task 2--Studies on the open Baltic
Task 3--Studies on water circulation in the Baltic
Task 4--Studies on dynamics of coastal waters
Task 5--Multidisciplinary studies carried out continuously at open sea stations
Task 6--Yearly biological observations enabling forecasting of future changes
Task 7--Studies on the levels of toxic substances in the sea environment.

In the framework of the Working Group a base-line study is carried out having, among others, the problem of intercalibration of the methods used thus far.

c) The Fisheries Improvement Committee spans its activity over all aspects of protection of the sea environment and its living resources.

Out of the other international organizations coordinating all Baltic countries and including the problem of pollution in the Baltic Sea in their own programs, the Conference of Baltic Oceanographers and the Conference of Baltic Sea Biologists should be mentioned.

As far as bilateral activity on these points in the Baltic countries is concerned, the following agreements of scientific collaboration are worthy of mention: Sweden-USSR (sea), Sweden-Denmark (Danish Sounds), Sweden-Finland (sea and Botunian Basin), and Finland-USSR (Gulf of Finland).

To accomplish realisation of the programs mentioned, the Sea Department of the Institute of Meteorology and Water Management in Gdynia, in analysing its organisational and technical possibilities, came to the following conclusions: (1) For the sea area, it should widen its statutory activity so that the Institute will deal with sea resources and quality of utilised water, a raw material now considered of basic and paramount interest, and (2) working with relevant scientific and technical facilities able to fulfill Tasks 1-4 of the Helsinki Convention program, the Department should organise a prognostic activity including the sea pollution problem.

In regard to the above, the possibility, aim and necessity of elaborating an adequate methodology, a technical and organisational model of water quantity and quality service is urgently needed. This would cover a wide area of water and combine the efforts, experience, and facilities of all Baltic countries and others, if necessary.

Because the problem is complex, a primary goal should be elaboration of the following:

(1) An optimal program of control measurements of the most essential parameters of physicochemical fields (hydrosphere, atmosphere, lithosphere)

(2) Universal technology for rapid analysis of distribution of these parameters

(3) Semiautomatic, high-speed, analytical methods

(4) Mathematical models of generation and decay processes of the pollution fields, taking into account programs for processing all collected data on digital computers in the National Oceanographic Data Centre

(5) A system of domestic and international distribution of data and forecasts.

Proper materials will be obtained as a result of organising and applying on broad sea areas two basic techniques of analysing the physicochemical fields, namely: techniques of analysis with the aid of a system of permanent measuring points and techniques of moveable measuring points analysis.

Analysis of the field by the first system, based on a defined number of coastal and sea measuring stations organised in a permanent telemetric system, is planned for application to physical fields of long-term dynamics, the latter being a subject of study in physical oceanography and marine meteorology. Tracing and reproducing the time variations, spatially smoothed structures of physical fields and operational prognosis of time and space variations of these fields (e.g., based on extrapolation of these changes, empirical and statistical, or mathematical models in order to develop a physical picture of pollution processes) will be executed throughout an active statutory hydrographic meteorology service. In addition to determining parameters, measuring method and requirements concerning the range and accuracy of the measurements, the project will describe other important features such as period of repetition of the program, density of the measuring net, amount and distribution of measuring levels, etc.; in this way the program will be successively improved. Critical evaluation of the effects obtained during the program establishment, together with the need to constantly improve forecasting methods, is seen as the basis for realisation of the first task.

The second technique is designed for application to analysis of fields with little time mutability, mainly chemical problems. Its achievement requires the help of laboratory measuring equipment coupled with semiautomatic sampling instruments in collaboration with a towed (by ship or remote control) vehicle to collect any samples required. The chemical parameters, measured over a series (or net) of grid points designed according to existing gradients, are to be transferred onto tapes or punched cards, or directly transmitted via radio to the operational center. Elaboration of the technical solution will enable execution of Tasks 2 and 3 of the given program. The data obtained will enhance the opportunity to trace and reproduce comparatively well a continuous picture of chemical fields and variations due to influence of physical fields and time span.

The junction of both fields through interaction of various external forces, described by numerical investigations, and using this knowledge for operational forecasting of property variations in the sea environment creates conditions for accomplishing Tasks 4 and 5, thus forecasting the effects of sea pollution.

It must be emphasised again that the Baltic Sea and its drainage area is an outstanding example of a difficult area for scientific studies. On the other hand, it is an excellent, almost universal model basin for the study of pollution problems wherein all problems of twentieth century technical culture are brought into focus.

Studies carried out in this basin have great importance as far as general knowledge is concerned, for a model concept can be assigned not only to the space scale but to the time scale phenomena as well, which is conducive to better understanding of all effects of coupling and interaction between technology and natural events.

It is obvious that for a realistically disposed man of this century, who tries to protect the sea environment by any kind of legal regulations, basic information on pollution and its effects must be augmented by knowledge of means and instruments for executing these by-laws. Therefore, elaboration of a model of sea service control and prognosis of variations in quality and quantity of the water constitute one of the basic tasks. This will help us ascertain if the sum of knowledge, collected throughout many years of costly studies, of effects of pollution on the natural environment can be properly utilised.

The encouragement for developing the project are due to positive results obtained during the progress of the PR-05.532-13 project carried out at the Sea Department of the Institute of Meteorology and Water Management. These studies contributed greatly to Tasks 1-4 of the Interim Commission and determined indispensable supplements to regional inland studies carried out in Poland. Organisational, technological and methodological experience gained during the realization of the proposed program will also be profitably carried over to other regions as well.

Well developed collaboration with the U.S. Environmental Protection Agency, opportunities for exchange of experiences and concepts with American scientists and their encouragement lead us to present our project with the hope that it will be of considerable interest in the EPA seminar devoted to sea environment studies.

MARINE POLLUTION RESEARCH IN YUGOSLAVIA: AN OVERVIEW

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Pollution concern is of recent origin in Yugoslavia, mostly because modest industrial capacity, low per capita energy consumption and low density of motor vehicles have kept pollution at tolerable levels. The eastern Adriatic shore has only in the last decade or so been endangered by intensive industrial development, mostly related to oil transport, port facilities, plastics, and metal industries. In addition, the tourist industry has grown at a rate far beyond expectation. Fisheries, tourism, and industry have begun to compete with sprawling urban development for land. It is therefore small wonder that pollution problems have arisen faster than legislation and the administration can cope with it. Due to specifics of geography and national economics it was unpracticable and nearly impossible to transfer only new, nonpolluting technologies, adopt foreign air, water, and land use standards, or impose limits to development.

It is not the aim of this paper to present an assessment of the present state of environmental pollution in the Adriatic region. There are still too few data available. Rather, we wish to show what approach has been taken in mobilising existing research institutions and their personnel in solving the most urgent problems. The research topics and the areas of intensive work have also been vehicles for bringing graduates in various natural sciences disciplines to enter this mission-oriented research field. This presentation and those of my colleagues are descriptions of the degree of success for an institution which, drawing on previously developed expertise in nuclear and materials science or in pure fundamental research, has taken new direction. All this has occurred in the last few years with limited funds and manpower in a society dedicated overwhelmingly to rapid development.

GENERAL CHARACTERISTICS OF THE ADRIATIC REGION: HYDROGRAPHY

Yugoslavia is located on the eastern Adriatic Sea shore, a landlocked gulf of the Mediterranean. Its northern part is a relatively shallow basin characterized by strong influence of terrestrial waters of Alpine origin. Depth increases toward the south, thus providing a reservoir for retention of much of its waters. The shoreline is 6,116 km along an airline of only 650 km, much of it due to indented shores of the numerous islands (4,020 km).

The northern part of the Adriatic, north of the Zadar-Ancona line (roughly one-third of the surface area) is disproportionately more important. It is the source of roughly 70% of its total bioproductivity and contains the largest concentration of urban and industrial development. Therefore, most of our recent concern with pollution has been located in the northern third of the Adriatic.

This shallow basin (Fig. 1) is also a specific estuarine region. The whole basin, roughly above 44°N, can be considered as influenced by terrestrial waters, mostly by the Po River, and to a lesser extent by the Adige River. The Po itself, along whose watershed approximately 70% of Italian industrial capacity is located, brings an average of 47 km^3/yr of polluted waters into the basin. The total estimate of water influx by a number of Alpine rivers is somewhere at 70 km^3/yr, although estimates differ (Nelson, 1970). Another characteristic feature is the large amount of sediments brought by these rivers into the northern Adriatic basin. The estimate for the Po River is 2×10^7 tons of dry material per year (Cerrai et al., 1970) causing, by some estimates, sedimentation rates of several centimeters per year (Schreiber et al., 1968). The salinity is high even near the estuary, due to the drift currents of highly saline Mediterranean waters up to the eastern (Yugoslav) coast, and a counter-clockwise rotation in the Gulf of Venice. Thus the salinity reaches 38.5 ppt in the northward currents and is of peculiar profile, 30-36 ppt very close to the estuary delta. Thus, all phenomena related to the transition from fresh to saline waters occur in a very narrow region of a few miles.

One of the better known characteristics of the northern Adriatic basin, and one closely allied to pollution effects on biota, is the nitrogen budget. Degobbis (1974) has shown that recycling accounts for 12×10^9 gram-atoms of nitrogen. About 5×10^9 gram-atoms of ammonia is liberated yearly by zooplankton excretion. The contribution from terrestrial waters, mainly the Po River, amounts to 8×10^9 gram-atoms, and the same amount is lost by current export from the region. The estimate for 1972-1974 shows that nitrogen contributions of sewage and rainfall are of lesser importance. This is an interesting indication of the area's high regenerative capacity. However, these figures vary with season and year, and eutrophic zones appear in spring and summer in the west, gradually changing to oligotrophic zones in the east. Recently, changes have been appearing in the regions along the Yugoslav coast, indicating increasing pollution load.

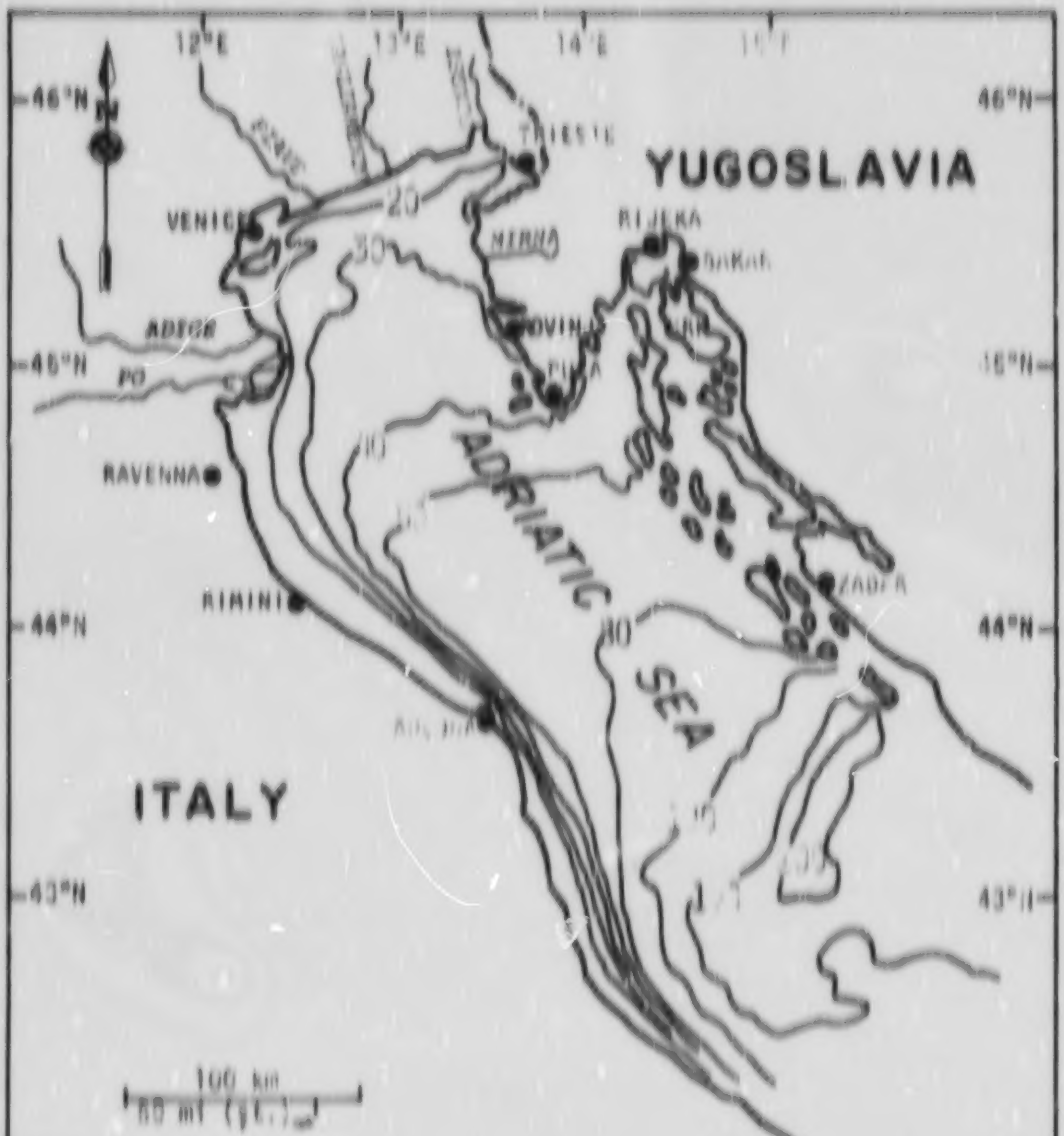
The hydrographical research includes monitoring the general parameters normally used in standard oceanographic surveys. They provide only the necessary background for pollution studies, and have been considered as baseline data. They include: (1) seasonal variation of common physical and chemical parameters (temperature, salinity, color, transparency, currents, pH, alkalinity, oxygen) and (2) seasonal variation of nutrients (total phosphorus, free phosphorus, nitrates, nitrites, ammonia).

RESEARCH ON MARINE POLLUTION

Pollution is specifically threatening the northern bioproductive part of the Adriatic and the narrow channels between the islands, location of much intensive and economically important tourist industry. The dilemma of the urgent need for fast industrial and urban development and the preservation of the environment has caused pollution research to gain recognition as a vital part of regional development planning.

Description of Research

The EPA-sponsored project "Integrated Studies of Marine Pollution in the Adriatic Sea," initiated in 1972 and completed in some specific tasks, has been the most vigorous Yugoslav effort to study the scientific aspects of pollution phenomena. Another important part of the effort has been the


12°E
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ANCONA
ZADAR
ITALY
ADRIATIC SEA
20
30
40
80
100 km
60 mi

Figure 1. Northern Adriatic bathymetric chart (depths in meters).

five-year UNDP-assisted project on the "Protection of the Human Environment in the Yugoslav Adriatic Region." The latter has been the basis for regional planning and only partly concerns marine pollution.

Most of the technology used in the new investments in production capacity (petroleum refining; petrochemicals; port facilities, including a deep-water oil terminal; power plants, including nuclear power) is imported from the developed countries, sometimes with little recognition of specific needs. Therefore, much of the research done by scientific institutions is a concerted effort to determine the dynamics of change in the marine and littoral environment, and to assess the predictable ultimate capability of a microlocation for receiving pollutants.

Until now there has been little feedback in reconsidering or redirecting industrial investments. Recognition of internationally acceptable standards of water quality for health, fisheries, recreation, and general amenities is emerging, but standards enforcement in the face of existing laws is lagging.

Among the more intensive and systematic studies of marine pollution, three fields related to specific tasks within the EPA-sponsored project should be mentioned. The first is related to determination of seasonal variations of concentrations of selected metal ions and their speciation in natural waters. More on this will be discussed by one of my colleagues in his presentation. The second is related to littoral communities in pollution-stressed areas, and, once again, more will be said about its aims and results in a presentation by another of my colleagues. The third project, "Interfacial Aspects of Marine Pollution," has been executed by the present author and will be described here in some detail.

RESEARCH OBJECTIVES AND RESULTS

The project has been divided into two interrelated but distinct parts. One concerns studies at the sea water/air interface, the other the sea water/sediment interface. Transport of matter across these interfaces, and the energetics of it, should relate to the ultimate capacity of an area to receive and retain nonbiodegradable (or at least slowly degradable) pollutants.

The Sea Water/Air Interface

In this research we have not been concerned with analytical measurements of actual concentrations. Indeed, such figures on a broader, international, scale would be at best one piece of information for some data repository. On the other hand, an approach to energetics of the sea water/air interface, specifically relating to real systems, would be of more general interest. We have tried to use simple techniques such as the surface tension and surface potential, and suggested one widely used and accessible substance, oleic acid, as the standard for measuring the state of the sea water/air interface.

A representative result for measurements relating to nearshore and port sea water is shown in Figure 2. It is the dynamic surface tension measurement for clean sea water (top curve) and for a sample taken from the contaminated part of the port with an untreated sewage outlet nearby (bottom curve). The curve between these is produced by adding measured quantities of oleic acid to the sea water shown in the upper curve.

Figure 3 shows a number of such curves simulating various degrees of surface contamination, expressed as the surface concentration of oleic acid. Thus, a viable standard of comparison and a simple technique are suggested for general intercomparison of polluted surface waters.

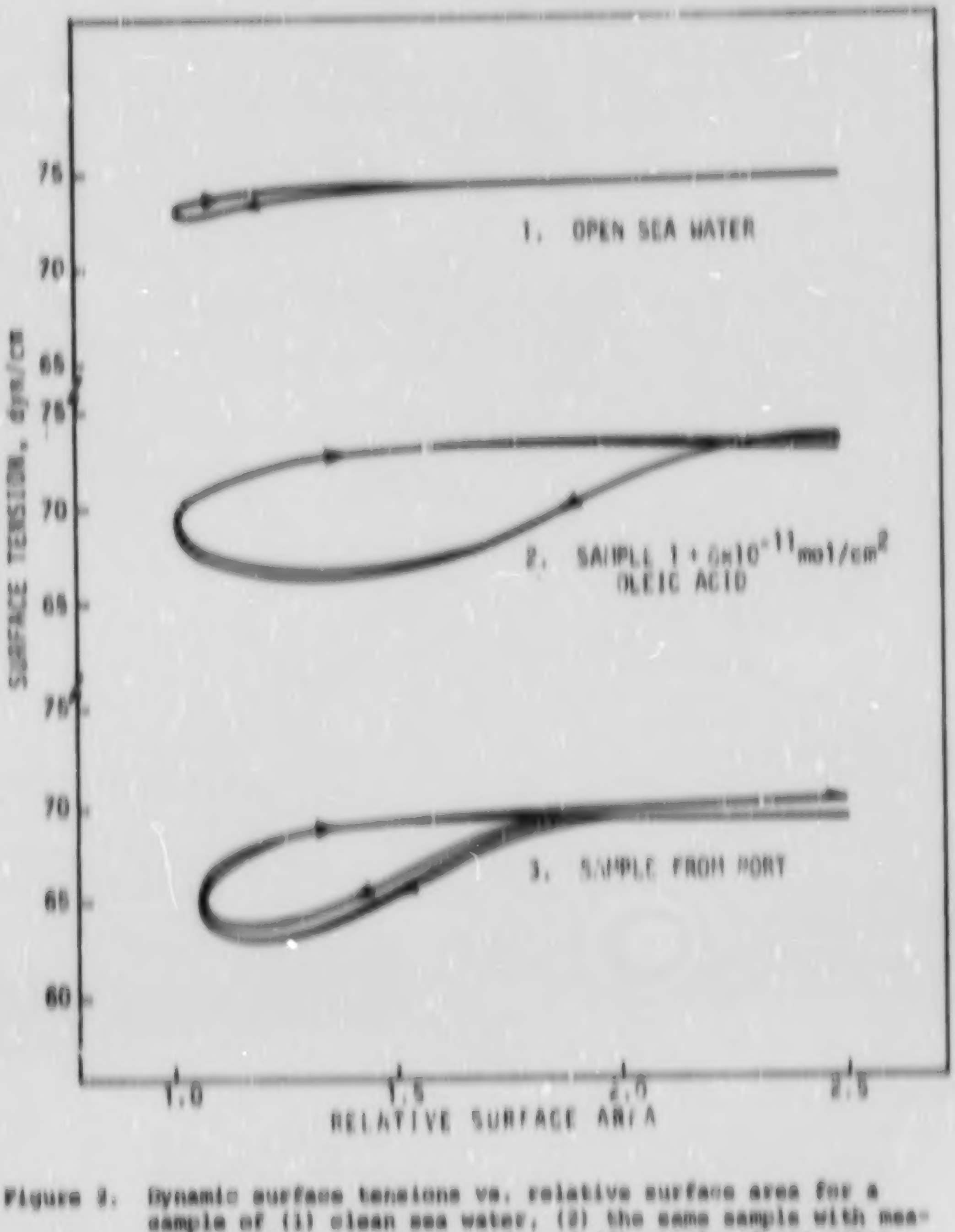

Figure 2. Dynamic surface tensions vs. relative surface area for a sample of (1) clean sea water, (2) the same sample with measured addition of oleic acid, and (3) sample of sea water from port near a sewage outlet.

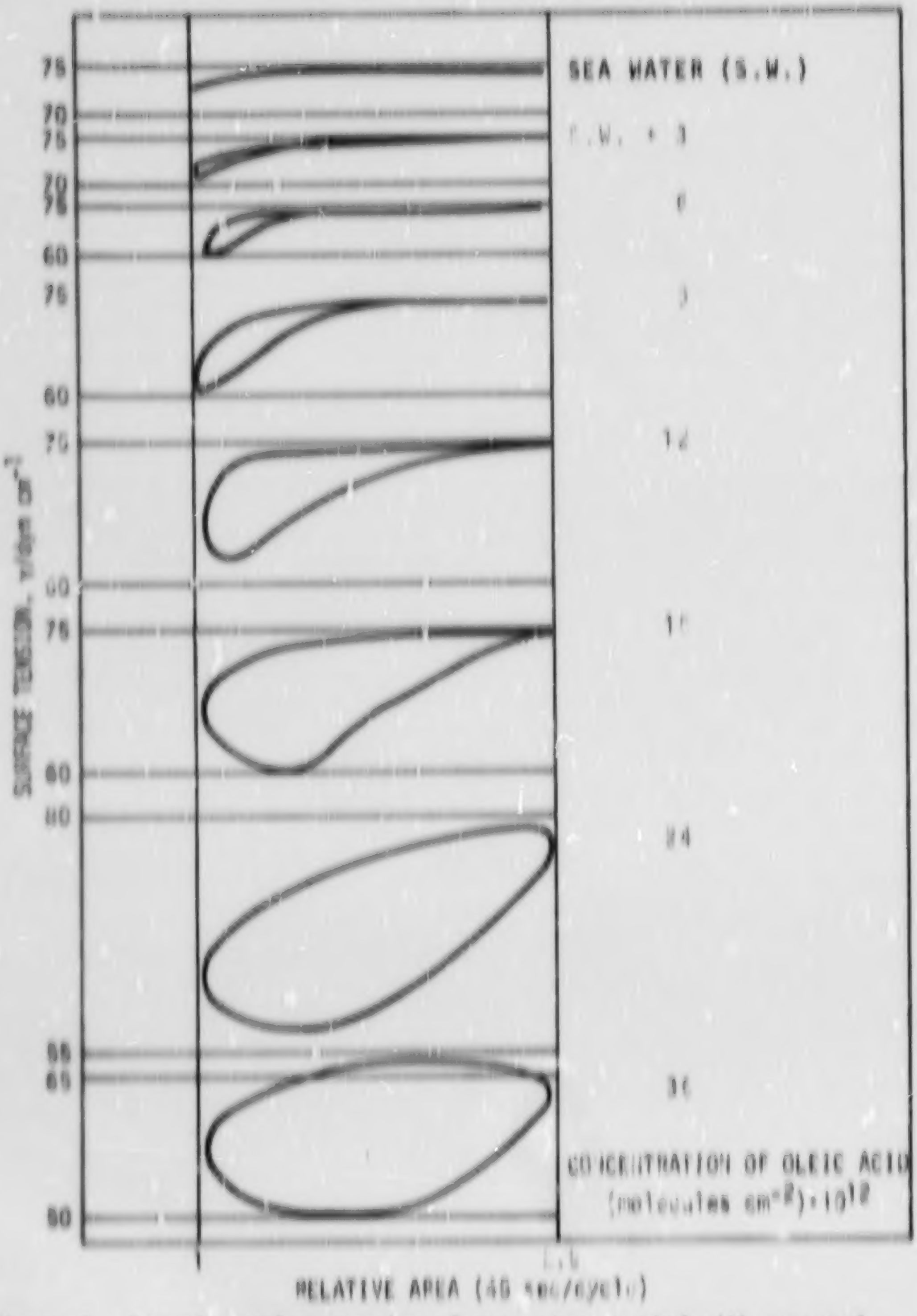

Figure 3. Dynamic surface tension of sea water treated with measured amounts of oleic acid.

The Sea Water/Sediment Interface

Another major part of the *project* relates to adsorption studies on sediments. The northern Adriatic basin receives, as stated above, some 20 million tons of river sediments per year. According to our measurements these sediments have on the average 17 m^2/gram of surface area (argon BET). This amounts to 3×10^{14} m^2 of new sediment surface exposed to sea water yearly. If all of this sediment were used as an adsorbent for a typical hydrocarbon (C_{15}, $M \approx 200$) it would be capable of retaining in excess of 10^5 tons of such a hydrocarbon per year. But the processes of adsorption are not that simple and these sediments bring with them a variety of other organic material, metal and radionuclide ions adsorbed into the area. It has been shown (Pravdić, 1970) that the estuarine region is the site of charge reversal and adsorption/desorption phenomena at the point where salinity reaches 6 to 20 ppt. Also, Martin et al. (1971) have reported on various general aspects of estuarine solubilization of trace elements. In view of this knowledge the still unanswered question is whether the suspended material reaching the northern Adriatic basin is supplying nutrient salts, polluting or regenerating the area influenced by it. Knowing the high sedimentation rates observed in the area, one is tempted to assume that a significant amount of various pollutants becomes imbedded into the sediments. This aspect could be most important in considering the retention time for radionuclides. However, the radioecology of sediments in the area is virtually unknown.

Returning to hydrocarbons and their interaction with sediments, our approach to studying the adsorption energies by heats-of-immersion microcalorimetry should be mentioned. In Figure 4, some characteristic data are being collected for a number of sediments of the area, which encompass both high and low carbonate content samples. On the left, data are given for the heats-of-immersion (integral heats of adsorption) of various technical hydrocarbons. At right there are, in the same scale, the heats-of-immersion for sea water and for two concentrations of a typical detergent dissolved in sea water. Although these values are integral values for clean, dry sediments and not substitutional values, it is indicated that the heats of interaction with water and detergent solutions are higher than for the hydrocarbons used. Consequently, one could hardly expect permanent retention of hydrocarbons, but rather some weak interaction and phenomena of "creeping." Thus, an answer has been approached on the use of marine sediments as adsorbents in accidental oil spills.

ACCOMPLISHMENTS TO DATE

In summing up the work reported here (much of it known from related research done in the Center for Marine Research), the last few years have produced a wealth of information on dynamics of pollution processes in the area.

One of the most noteworthy events of 1973/74 has been the cruise of the research vessel *Vila Velebita*, repeating the northern Adriatic route surveyed by its namesake 60 years ago ([illegible] et al., 1973). The data, although difficult to compare, are being prepared for publication (Ravodnik, in preparation).

An accomplishment of special importance is research related to thermal pollution by power plants. Large oil-fired units are in construction,

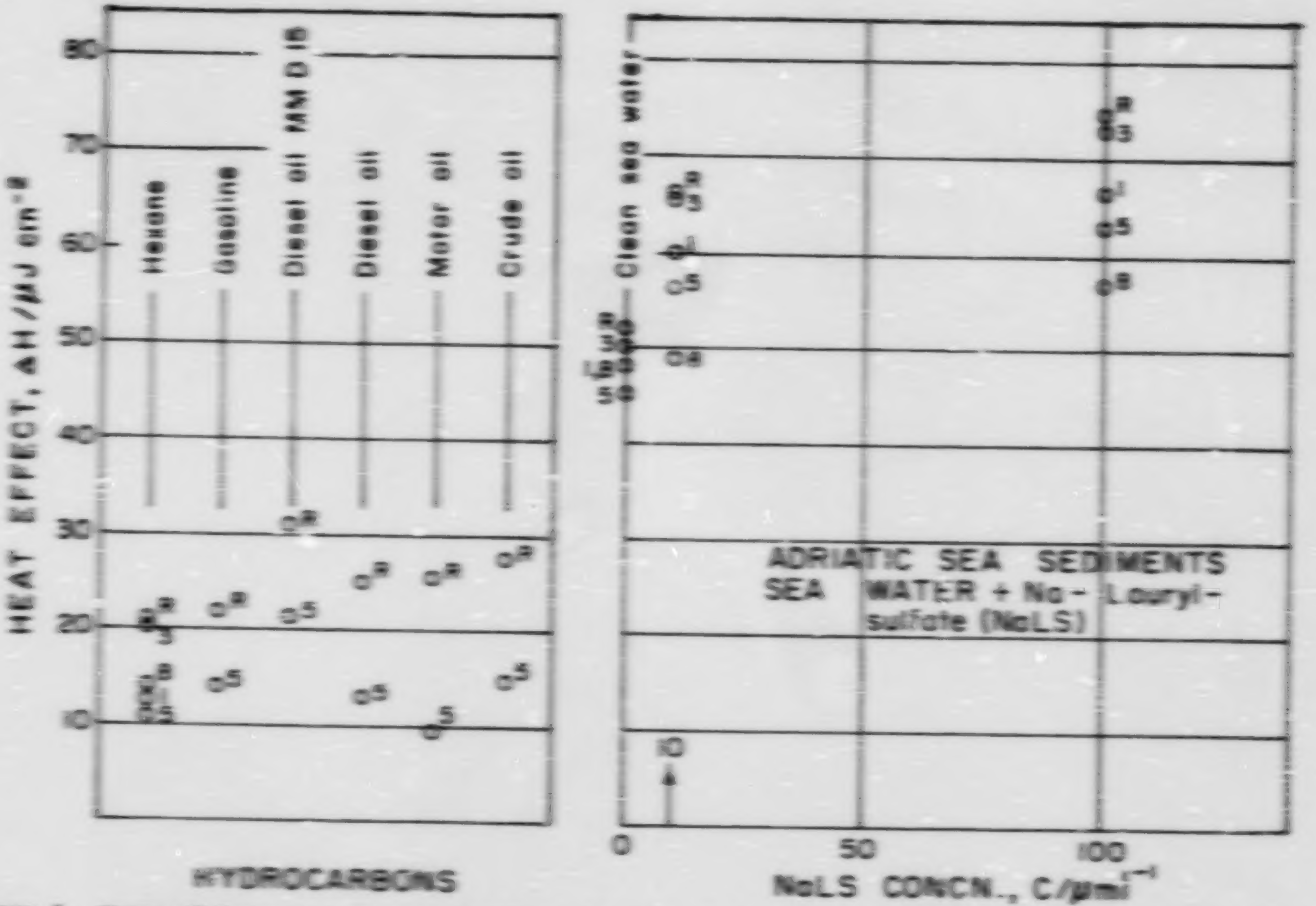

Figure 4. Heats-of-immersion of shallow water sediments ("R" sample of high carbonate content, "S" low carbonate content, others in between) for some petroleum hydrocarbons, clean sea water, and sea water with detergent (sodium laurylsulfate).

and at least one nuclear station is planned, both using sea water as a coolant. Advances have been made in thermal plume modelling using the Shirazi-Davis model. Application of these models for minicomputers is in progress. Also, attempts were made at producing conceptual and mathematical models for the area using the large computing facilities available in Zagreb (Shirazi and Davis, 1974).

Most importantly, a number of researchers have been trained in pollution studies, and while many have not remained permanently in the Center, they have carried with them the knowledge of methodology, techniques and, last but not least, proper scientifically documented concern for threats of accelerating pollution.

FUTURE PLANS

The continuation of the efforts initiated a few years ago and generously supported by the EPA is receiving proper dimension in recent developments. The decision was made to locate a deep-water oil terminal in the Bay of Rijeka, and an adjacent petrochemical complex on the island of Krk. The Center has been called upon to produce environmental impact statements by the local authorities. A three-year master plan has been co-developed by the present author and his colleagues at the Center, with collaboration of other institutions in Split, Dubrovnik, Rijeka and Zagreb. Other plans call for construction of a 1000-MW nuclear power plant near Zadar, requiring thorough environmental baseline and water dynamics research, specifically with respect to radioecology. It will be a run against time, since few data are presently available at specific microlocations. Those existing for the broader area suffice only for the most general conclusions, not for the assessments of amplitudes and of seasonal variations in specific hydrographic parameters. By taxing the investments with a modest percentage of their total cost, environmental research will receive support in the years to come.

Establishment of general water quality criteria by the GESAMP-FAO-WHO working groups will bring local communities and their tourist industries under pressure to conform with such criteria. All aspects of environmental research will be required to provide assessments of feasibility of concurrent economic development for both large industrial complexes and for recreational areas. In the long run, it appears that environmental expertise and research capacity will be in short supply to fulfill all the tasks. Therefore, training and educational capacities must be strongly supported now and in the immediate future.

The example of Yugoslavia and the Adriatic may become an important test case for a large part of the world. The problem is: Can rapid economic progress of a less developed country be accomplished without irreparable damage to the human environment? If our test case shows positive results, then many other countries of the developing world could be convinced that the controversy of development vs. pollution can be resolved using new technology.

ACKNOWLEDGMENT

The U.S. Environmental Protection Agency, through its Special Foreign Currency Program and bilateral agreements, has substantially helped in initiating many aspects of environmental pollution research in Yugoslavia. Our specific thanks are due Mr. Thomas J. Lepine, Office of International Programs, for his initiation of such a coordinated effort in marine sciences; Mr. Robert B. Quinn, formerly of the same office, who outlined the philosophy of the whole approach in its initial stages; and Mr. T. A. Wastler, Chief, Marine Protection Branch, who has monitored its progress in the last three years. Through their help we have also come into contact with a large number of United States scientists who have helped us with their advice and criticism.

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OVERVIEW OF MARINE POLLUTION RESEARCH IN EGYPT

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Several Egyptian institutions are involved with aquatic pollution problems, especially the Water Pollution Laboratory at the National Research Centre, Cairo. Their main areas of interest are water quality and industrial waste in the Nile and its tributaries. Currently, the Academy of Scientific Research and Technology has signed a five-year bilateral agreement on a project, "Water Quality Studies on River Nile and Lake Nasser," a collaboration of research teams from Michigan University and Egypt. This project is funded by the U.S. Environmental Protection Agency (EPA), with support of the Ford Foundation.

Institutions involved with marine pollution problems are the Institute of Oceanography and Fisheries, Academy of Scientific Research and Technology; the Department of Environmental Health, High Institute of Public Health; and the Departments of Oceanography, Sanitary Engineering, and Plant Protection, Alexandria University.

Coordination among these institutions is effected through the Council for Environmental Research of the Academy of Scientific Research and Technology. The Council has set up a committee for environmental pollution which defined four major areas in Egypt subjected to effects of different pollutants. These are Alexandria, Helwan and Shubra el-Kheima near Cairo, Aswan, and the Gulf of Suez, with a subcommittee for each area. Alexandria was given priority since serious water pollution problems exist or are developing in the fresh, brackish and marine environments.

At present, the untreated sewage of central Alexandria (over 2 million inhabitants) is discharged into the sea through a pipe constructed in 1954 (length, 735 m; depth -16 m MSL), with a daily discharge of 150,000 m^3 from about one-third of the city sewage. There are, additionally, several emergency openings along the coastline. Thus, it is possible that the Alexandria beaches will be the first national recreation area to be polluted, with the anticipated effect on area seafood. One-third of Egypt's industrial activity is located in the Government of Alexandria where several factory complexes exist, mainly an oil refinery, paper mills, textile and cement manufacture, chemical industries and copper works. An oil pipeline terminal, connecting the Gulf of Suez with the Mediterranean, will reach the sea about 50 km west of Alexandria and will transport about 80 million tons annually, with a possible increase to 120 million tons. Completion of the project is expected in 1977 and, although all precautions have been taken, there is still the possibility of oil spills at this site during loading operations and the coastal estuaries are liable to be affected.

At present, tar balls and oil slicks occasionally spread along the beaches east of the Alamein oil field terminal, about 100 km west of Alexandria. Industrial wastes, especially from paper mills and a chemical dye factory east of Alexandria, are already discharged into Abou Qir Bay through El-Tabia Drain and a graduate research program carried out there revealed its effect on the Bay ecosystem.

The sewage from the eastern and western parts of the city, as well as industrial effluents from 15 factories, is dumped into Lake Maryout, a coastal lagoon bordering Alexandria from the south. Two drains receiving discharge with pesticides present from the cultivated land west of the Nile Delta flow into the lake. The lake deteriorated and its fish production decreased during the last decade from about 12,000 tons to 1,900 tons annually. The subcommittee for the Alexandria area, in view of this situation, recommended to the Council of Environmental Research two inter-institutional projects on aquatic pollution: (A) Effect of sewage disposal in the sea on the water quality along the beaches of Alexandria and (B) Pollution control in Lake Maryout. The two projects were contracted between the Academy of Scientific Research and Technology as the funding agency and Alexandria University as the executing agency.

The second project may seem to be outside the theme of this marine-oriented symposium, but I would draw your attention to the fact that Lake Maryout lies about 3 m below sea level and the lake water is continuously pumped into the sea at El-Max site to protect the cultivated land from overflow. Thus, the different pollutants discharged into the lake find their way to the sea.

To summarise the objectives and outlines of the two projects:

A. Effect of sewage disposal into the sea on the water quality along the Alexandria beaches:

Objectives

1. Classification of the beaches according to their suitability for recreation and swimming.
2. Study of the effect of sewage pollution on marine organisms (plankton and benthos).
3. Presentation of recommendations for the necessary degree of sewage treatment before disposal into the sea and promulgation of legislative measures to protect the inhabitants from any pollution hazards.

Outline of Project Plan

1. Physical and chemical analysis of sewage to measure seasonal changes in the pollution load discharged into the sea.
2. Study of coastal circulation in the area to determine the path of pollution and the use of tracers (dyes and possibly radioactive isotopes) to determine pollution dispersion along the shoreline.
3. Investigation of physical and chemical characteristics of sea water and analysis of bottom sediments in, around and away from the disposal region.
4. Quantitative and qualitative studies of plankton and algae, and effect of sewage on areal biota.
5. Microbiological, virological and epidemiological studies to assess water-borne diseases transmitted to swimmers.
6. Classification of beaches according to degree of pollution.

B. Pollution control in Lake Maryout:

Objectives

The Alexandria sewage disposal authority established a sewage treatment plant providing primary and secondary treatment before discharge into the lake and is now in the testing stage. It also established another plan for treatment of industrial effluents from 15 factories at the lakeside. This project will investigate existing conditions in the lake and evaluate the hygienic, engineering and economic aspects of the above mentioned plants directed toward controlling pollution in the lake and reviving its fish productivity.

Outline of Project Plan

1. Comprehensive chemical, biological and microbiological survey of all industrial and domestic wastes discharged into the lake.
2. Survey of all drainage canals opening into the lake to detect the presence of pesticides and measure the organic and inorganic pollution load from these drains.
3. Periodic analysis of the lake water (physical, chemical and microbiological).
4. Study of the fauna and flora in the lake and the effect of pollution on lake productivity and estimation of organic production.
5. Studies on the water level, rate of evaporation and lake self-purification.
6. Study of public health aspects with special emphasis on parasitic, bacterial and skin diseases among fishermen in the lake area.
7. Study of alternatives for waste treatment before disposal, and proposal of ways and means for pollution control to serve as a guide-line for the future plans of the Alexandria sewage disposal authority and the Ministry of Irrigation.

The laboratory and field studies for the two projects are carried out by research teams from the following: the Departments of Public Health, Microbiology and Epidemiology of the Institute of Public Health, Alexandria University; the Departments of Oceanography and Sanitary Engineering, Faculty of Science, Alexandria University; and the Institute of Oceanography and Fisheries, Mediterranean Branch, Alexandria.

Field observations and collection of samples are carried out as frequently as possible (mostly bimonthly) and analyses are performed by the various standard methods with minor modifications whenever necessary.

For the time being, data are kept in the form of preliminary reports but in the near future we intend to use the formats now being prepared by an expert group of the IODE Working Committee of IOC for marine pollution data, and process this information at our National Oceanographic Data Center in the Mediterranean Branch of our Institute.

While preparing the operational plans of these two projects, we deemed it necessary to request technical assistance from UNDP in order to upgrade our chemical analytical capabilities and to train national staff on modern analytical techniques for advanced trace analysis. Consequently, a UNDP project (No. EGY/73/058/B/01/13) is being prepared, entitled "Pilot Project for Aquatic Pollution Centre at the University of Alexandria." Its duration is three years and the contribution requested is about \$100,000, which will be used mainly for equipment and training fellowships.

The long-term project objectives are the establishment of a centre for surveying pollution of the aquatic environment and suggesting methods for pollution control and abatement. The Centre will also assist the authorities in developing and applying, on a national scale, a coordinated program of research in the field of water pollution.

The immediate objectives of the project are to assist the authorities in developing and coordinating a research program to solve the urgent major water pollution problems in the Alexandria area, also to provide graduate studies and training of specialists in all aspects of water pollution. Actually, those projects underway are our immediate objectives and this UNDP project is to be an additional allocation to the funds from the Academy of Scientific Research and Technology.

FUTURE PLANS

For the future, I see need for increased effort in monitoring and research of pollutants in our marine environment. When the nucleus of specialists in Alexandria is well established and has gained experience, the personnel then move to other areas where related problems are anticipated.

Two actions last year point the way to our participation in regional activities in marine pollution monitoring and research.

First, the UNEP invited the Mediterranean countries to an Intergovernmental Meeting on Protection of the Mediterranean (Barcelona, 28 January-4 February 1975). The conference adopted a plan of action including early implementation of seven pilot projects in the frame of a Coordinated Mediterranean Pollution Monitoring and Research Programme. These seven pilot projects are: (1) baseline studies and monitoring of metals, particularly mercury and cadmium, in marine ecosystems; (2) baseline studies and monitoring of DDT, PCBs and other chlorinated hydrocarbons in marine organisms; (3) research on the effects of pollutants on marine organisms and their populations; (4) research on the effects of pollutants on marine communities and ecosystems; (5) baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters; (6) problems of coastal transport of pollutants; and (7) water quality of coastal waters.

These seven pilot projects will be executed by national research centers and their execution will be closely coordinated by UNEP, FAO, IOC, WMO and WHO. During 1975 UNEP convened a consultation series for groups of experts from the region, who prepared the operational documents for these projects. These documents were submitted to the Mediterranean Governments, who were asked to nominate their national research for participation in the projects. The Mediterranean Branch of the Institute of Oceanography and Fisheries, Alexandria, was nominated as the National Center which will participate in these projects with the collaboration of the Oceanography Department and the Institute of Public Health, University of Alexandria. In addition, our national programs are considered as parts of these pilot projects in the Mediterranean. Funds are available at UNEP to support participation of the national laboratories in the pilot projects, particularly those from developing countries in the region.

In the meantime, we are preparing a draft proposal for the establishment of a "Mediterranean Marine Pollution Assessment Centre" at the Institute of Oceanography and Fisheries, Alexandria, which will be submitted to NOAA, U.S. Department of Commerce, for support from the Special Foreign Currency Program (PL-480), besides the anticipated support from UNEP and other sources.

This Centre will undertake the following activities: (1) regional coordination of Eastern Mediterranean marine pollution monitoring and assessment activities; (2) distribution of sampling devices and the associated curatorial supplies; (3) analysis of samples from the international waters of the Eastern Mediterranean Sea, collected and contributed by collaborating countries; (4) collaboration with a designated Centre for quality control of sample analyses as part of the Quality Assurance Program; and (5) preparation of pollution data summaries for distribution to all users. Adequate laboratory space for the Centre's work will be furnished in a new annex building at the Mediterranean Branch of the Institute of Oceanography and Fisheries, Alexandria, to be ready within three months.

In the Red Sea region, similar activities took place by the end of 1974 when ALECSO, with the support of UNEP, convened a meeting in late November for experts from countries bordering the Red Sea and Gulf of Aden. A plan of action for protection of the environment of the Red Sea and Gulf of Aden was agreed upon. During 1975, groups of experts from countries in the region prepared documents on a coordinated program for monitoring and research of pollution as well as a regional oceanographic program. The second meeting was also held at Jeddah (early January 1976) and the participating countries have approved the plan, which includes implementation of two pilot projects related only to oil pollution and its effect on marine organisms (taking into consideration that oil at present is the main pollutant in the region and that the national capabilities of the countries in the area must be strengthened at the start in the field of marine sciences).

The Red Sea Branch of the Institute of Oceanography and Fisheries at Suez and the Marine Station at Al-Ghardaqa are the national contacts for participation in the regional program of the Red Sea and Gulf of Aden.

From the foregoing presentation, I hope that our future plans are so specific that interested institutions and agencies can choose the areas of interest for cooperation, provided that on the national level we are preparing the necessary requirements for implementation of these projects within our limited funds. Our needs will be mainly confined to field and laboratory equipment, training of staff and expert service in the field of marine pollution.

OVERVIEW ON POLLUTION IN THE COASTAL ENVIRONMENT OF PAKISTAN AND ITS POSSIBLE IMPLICATION FOR THE MARINE ECOSYSTEM

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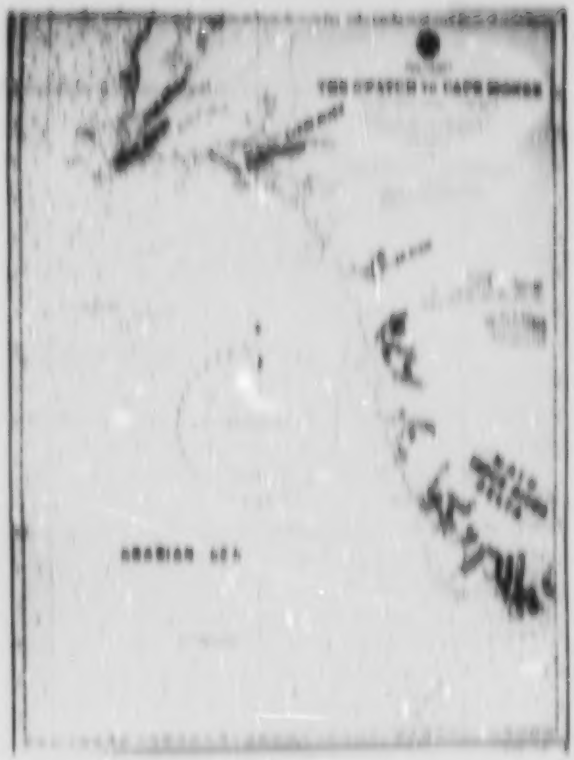
INTRODUCTION

Pakistan has a 550-mile long coastline with more than 20,000 sq mi of area as part of the continental shelf. The coast is comprised of the Sind and Baluchistan sectors (Fig. 1). Along the entire coast the most important area affected by natural causes and pollution is the region of Karachi and its adjacent network of creeks. Karachi is the largest city in terms of population and industrialization, and is also the largest port in the region. There is evidence that both natural factors and man's activities in this region are affecting drastic changes in its environment. To deal with problems of resource conservation and protection of coastal environments, it is imperative that, at the outset, factors complementing the change be thoroughly examined.

Since the creation of Pakistan in 1947, there has been considerable population growth and concurrent development in agricultural and industrial sectors. A predominant feature of this growth has been the urbanisation in Pakistan since 1947. While the total population of the country has increased 2.7% annually, the urban population increase has been as high as 4.7%. In 1941, the total population was 28.3 million with urban areas at 4.0 million as compared with present figures of 86.8 million and 20.3 million, respectively. By the year 2000, the total population is expected to reach 130 million and urban about 65.0 million (50% of the total). An important feature of urbanisation in Pakistan has been the development of large cities and towns along the only major river of the country, the Indus (Fig. 2), which flows from the Himalayas. It collects water from its four important branches in the Punjab and travels more than 1,000 miles before emptying into the northeast Arabian Sea, about 50 miles south of Karachi. Historically, the Indus has been the cradle of ancient and present civilisation for 5,000 years. Since urbanisation necessarily involves development of trade, commerce and industrial activities, it is to be expected that the Indus River would be the receptacle for industrial and domestic effluents from major urban areas.

The city of Karachi has a population of 5.2 million. In 34 years the population increased roughly 10 times and by 2000 is expected to rise to about 15 million. The city is Pakistan's largest industrial base with no fewer than 800 industries; it is also the largest port and commercial center, and is thus a major contributor of pollution to the coastal environment.

Figure 1. South coast of Pakistan showing region extending from Cape Monze to Khari Creek


ARABIAN SEA

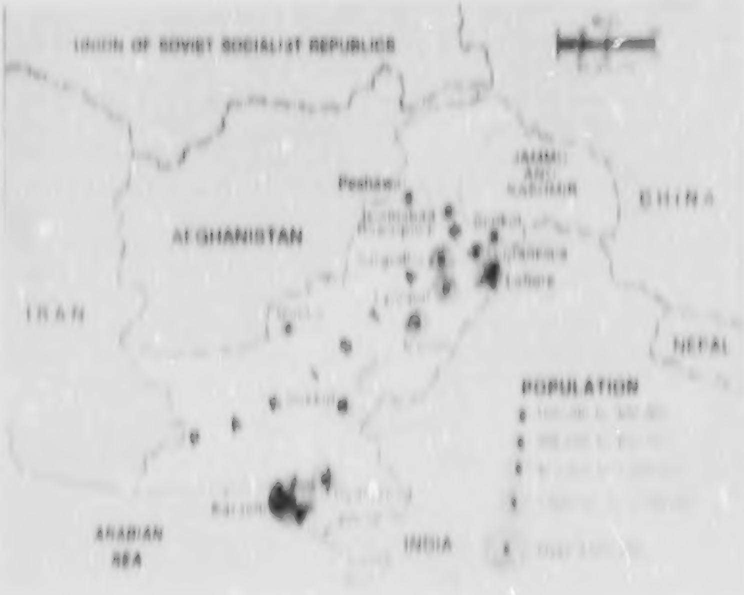

UNION OF SOVIET SOCIALIST REPUBLICS
JAMMU AND KASHMIR
CHINA
Peshawar
AFGHANISTAN
Lahore
IRAN
NEPAL
POPULATION
Karachi
ARABIAN SEA
INDIA

Figure 2. Pakistan major urban centers, 1971

PHYSIOGRAPHY AND HYDROGRAPHY OF AREAS AFFECTED BY POLLUTION

Karachi is located at the northeastern border of the Arabian Sea. From both environmental and hydrographic points of view, there are three important areas where human activities affect the coastal environment, namely, Manora channel/Karachi harbor, Hawks Bay, and creeks and adjacent coastal area.

Manora Channel

This is a semi-natural harbor protected by Manora Island and spread over an area of 7.17 km^2. The average volume of sea water entering and leaving the channel is about 3.4 million m^3. Apart from serving as the main harbor, the channel has a vast area forming western and eastern backwaters characterised by mud flats and mangroves rich in fauna. At the western backwaters the Lyari River outfall is one of the principal basins through which domestic and industrial effluents are discharged. The channel entrance is narrow and easily silted, and is maintained by dredging about 456,000 m^3 of silt annually (G. S. Quraishee, personal communication).

Hawks Bay

Hawks Bay, representing the body of water enclosed in the semicircular coastline between Cape Monze and Manora channel, is an important fishing ground for shrimp and fish. From Cape Monze eastward up to Bhole Ji the coast is rocky but the remaining portion up to the Karachi backwater is low and sandy. In this area the deep water is close to shore, the slope gradient being 1 in 15 ft from the low water line. The Karachi Nuclear Power Plant (KANNUP) is located near Paradise Point, which discharges its effluents into the area. North of Cape Monze, the west coast is characterized by small sandy bays and sandstone hills and, at some places, igneous rocks. The deeper water in this area is very close to shore, having a slope gradient of 1 in 10 ft. Slightly north of the Hub River is situated the "Ship Wreck," a recent establishment for scrapping of ships. Oil slicks and other contaminants discharged into the sea are a potential hazard to area marine life.

Creeks

Immediately south of Karachi is a complex network of creeks, all tidal except for the main tributary of the Indus River. Their salinity is typical of the coastal waters. The most important from a pollution point of view are the Ghizri, Korangi, Gharo and Phitti creeks. Generally, the creeks' vast area is dominated by thick mangroves which are partially inundated at high water. That area exposed at low water is muddy, with fine silt deposits. The low surf action in the intertidal zone plus aggregation of organic matter in the subsurface area has been contributing to formation of a thick layer of black mud just below the surface with anaerobic conditions, combined with hydrogen sulfide. The creeks offer shelter to many marine animals which live near the thick mangroves. It also serves as nursery and spawning grounds for many important species of pelagic fish and shrimp, and form a permanent habitat for a large species of mud oyster (*Crassostrea rivularis*).

Tides

The tides near Karachi advance from the west to the east coast. Tidal heights increase gradually from west to east. The nature of the tide is semidiurnal with marked diurnal variation.

Table 1. Tidal heights of important localities near Karachi[a]

Locality	Mean spring height (ft)	Mean neap height (ft)
Gadani	8.0	6.9
Hawks Bay (Cape Monze)	8.5	6.8
Karachi harbor	8.8	6.8
Phitti Creek	9.6	6.7
Inside creek (Pipri)	11.1	6.4

[a]Data from Tide Tables, 1975, by G. S. Quraishee.

Waves

Predominant winds in Karachi and vicinity during the southwest monsoon are southwest from mid-May to mid-September. The winds during this period are about 25 knots, having a long fetch over the Arabian Sea. Consequently the swell rolls along the coast to a height of 10-12 ft at 10-second periods. During the northwest winter monsoon the winds are light, 5-10 knots, and the sea is usually calm. In the remaining months the winds are variable, giving moderate seas.

Wind and Wave Induced Currents

The general oceanic circulation in the two summer and winter monsoons creates a clockwise gyral in the southwest monsoon and anticlockwise in the northeast monsoon. The speed of the oceanic current is 1-2 knots. During the southwest monsoon the longshore current, due to waves breaking near the shore, is 0.5-1 knot and southeasterly in direction east to Cape Monze; north of Cape Monze it is northerly.

Upwelling of Deoxygenated water

During the southwest monsoon upwelling of oxygen-deficient subsurface water results (Doe, 1965). At times water with O_2 of 1.7 ml/ℓ is found at a depth of 15 m. Banse (1968) suggests that deoxygenated water remains in most of the shelf during summer and most of autumn and probably recedes by December or January. By March most of the shelf is covered with aerated mixed water.

Influence of the Indus on Ecology of Creeks and Coastal Waters

Around the 16th century, the Indus flowed through the Kairi branch, presently known as Gharo channel (Fig. 3). The Korangi, Phitti and Khuddi creeks represent the remains of the Kairi's course. According to Homes (1968) the Kairi course was predominant in 1519 and some time later the main flow shifted to Baghar creek as the major outlet in 1819 with its principal distributions Khai, Pitiani and Dobbo creeks. After 1819 the Ochito course carried the main flow, and the Hajamro and Turshian creeks were its principal distributaries. The Ochito course was abandoned in the present century to Khobar creek some 47 miles from Phitti creek. Wilhelmy's (1966) exhaustive survey also suggests that the deltoid region has advanced shoreward approximately two miles. This is also exemplified by the contours. The vast area of land in the entire network of creeks is characterised by thick mangroves and great diversity of fauna.

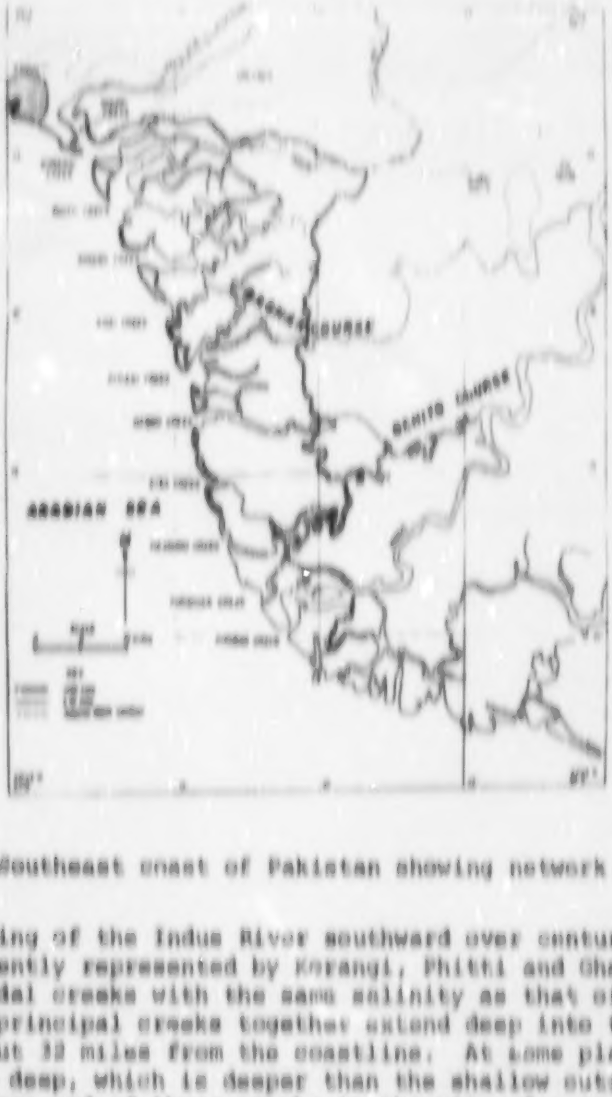


Figure 3. Southeast coast of Pakistan showing network of creeks

The shifting of the Indus River southward over centuries turned the old delta, presently represented by Korangi, Phitti and Gharo creeks and others, into tidal creeks with the same salinity as that of coastal waters. These principal creeks together extend deep into the land for a distance of about 32 miles from the coastline. At some places the creeks are about 70 ft deep, which is deeper than the shallow outside coastal water; the eastern end of these creeks is the site of a new harbor, port Mohammad Bin Qasim, and a steel mill, both under construction. Because of narrow entrances to the creeks and shallow bars the tides at times enter at a speed of 3 knots. The complex network of creeks favors convergence of water at high water in a few main creeks (e.g., Korangi and Phitti); consequently the ebb is stronger (above 5 knots) than the flood.

The stronger ebb causes scouring of creek basins and aids in transporting sedimnnts back into the coastal area.

The distance between the mouths of Korangi and Phitti creeks (Bunda Island) to Ghuro (Pipri), at the farthest end inside, is about 32 miles. Due to this long distance the high water at Pipri appears much later than at the mouth of the creeks so that before the tides completely fall at the former, it starts rising at the mouth, which at times may obstruct the flow of water outside into the coastal area. This may affect the discharge of effluents accumulated at the farthest end outside the creeks.

Influence of Indus on Coastal Environment

During June and July the Indus is reported to have a discharge rate of 350,000 cfs as compared with 5,000 cfs in winter (Quraishee, 1975). Whereas most of the sand tends to settle long before the confluence of the river, the bulk of the finer silt is discharged to the coast. It is estimated that the summer siltation is of the order of 4,000 ppm as compared with 500 ppm in winter and this complements the plume of silt at the Indus confluence, extending 15 miles (Quraishee, 1975). In winter, the plume is reduced to only 5 miles. The longshore current and the currents of the southwest monsoon further contribute to the spreading of the sediments along the coastline. In comparison, silt deposits within the creeks are relatively less because the stronger ebb causes scouring of creek basins. Thus, variations in silt deposit in main creek basins and outside coastal area markedly influence the coastal configuration and environment, which in turn may affect the biology of the area.

PRESENT KNOWLEDGE ON POLLUTION IN COASTAL WATERS

Industrial and Domestic Sewage

In the Karachi area, sewage of industrial and domestic origin constitutes the major source of pullution in the coastal environment (Fig. 4). The Master Plan Department of Karachi has carried out a survey of waterborne pollution expressed in terms of BOD values (Karachi, 1972). The total pollution from the city is estimated at 1,237 tons/day of BOD. The residential zone accounts for 12.3% of the total BOD, of which 97% is due to housing and the rest to health, administrative units, educational centers, etc. The industrial zone of the city is by far the largest contributor of waste disposal, amounting to about 84.5% of the total discharge (1,040 tons/day of BOD) from the city. The city's large industrial areas are SITE, LITE, Korangi Industrial area and West-Wharf, where no fewer than 800 large and small industries are located. The most important large industries are food and beverages, paper and paper products, tobacco, textiles, rubber products, chemicals, non-metallic minerals, basic metal industry, metal products, machinery, and products of petrol and coal, which contribute 99% of the total industrial pollution. The SITE sector, the largest, contributes 51% of the total pollution from the industrial zone. The textile industry contributes about 89% and the chemical industry about 8% of the total industrial pollution.

The agricultural zone in the Karachi urban area contributes only 3.2% of the total city pollution. The technical infrastructure zone, representing largely the transportation and utility nodal points, accounts for 52 tons of BOD per day.

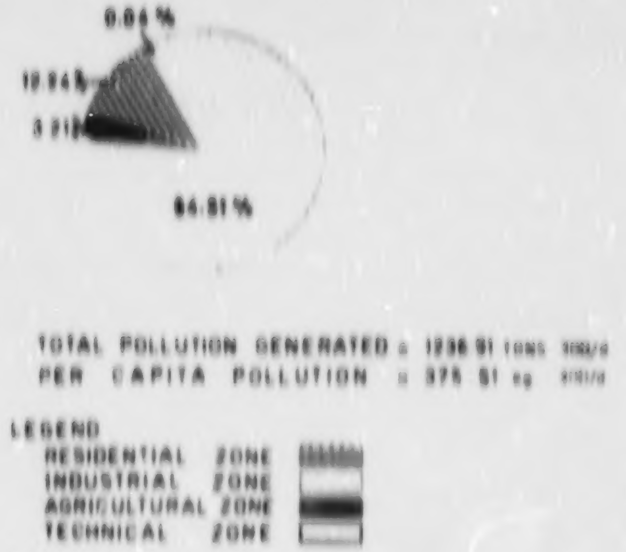


Figure 4. Composition of pollution in Karachi urban area.

The sewerage system of urban Karachi is grossly inadequate, at present composed of two districts. Each district has one treatment plant, three shifting or pumping stations, and trunk sewers. The treatment plants have varying efficiencies for treatment of solids, volatile solids, grease, etc. The bulk of District I pollution, about 615 tons/day of BOD, is of industrial origin, mainly from the SITE area. Of this, only 3% (representing about 8 MGD of sewage) is carried to the District I treatment plant and the final effluent is discharged along with the remaining portion into nullahs and the Lyari River, and finally into the western backwaters of Manora channel.

In Table II, effluents are analysed and their annual discharge from the Lyari is given. It can be seen that a significant amount of total dissolved solids is in the form of organic matter (10,555 metric tons), ammonial (805 metric tons) and albuminoid nitrogen (18.9 metric tons), and phosphate (917 metric tons), which are discharged annually through the Lyari into the western backwaters of the channel. This provides eutrophication and enrichment of the channel waters. Addition of compounds of sulphate, calcium, aluminum and magnesium may also modify areal biota. Of particular importance is arsenic, which is discharged in significant amounts into the sea.

In District II, located in the south, the total pollution discharged amounts to about 550 tons/day of BOD, both industrial and domestic in origin. The treatment plant in this area can handle 3% of the total pollution which, along with the remaining portion, is discharged through land disposal and open water drains into the sea at Gizri creek. Compared with District I, this area is relatively less industrialized and receives effluents largely from LITE and other areas southeast of Karachi. A significant disposal fraction is expected from the housing sector, hence the discharged effluent should be mainly human waste disposal. A systematic survey of pollutant composition from different sources needs to be studied further, as in none of the districts are the largely untreated effluents controlled or removed at the source.

Table 2. Waste flowing into the sea from the Lyari River
(metric tons)

Composition of waste	Daily	Yearly
Chloride	152.46	53,200.0
Sulphate	151.74	53,109.0
Suspended solids	34.20	11,970.0
Total dissolved solids (TDS)	376.20	131,070.0
Organic matter in TDS	47.34	16,555.0
Ammonial nitrogen	2.30	805.0
Albuminoid nitrogen	0.05	18.9
Total nitrogen	2.35	822.5
Alkalinity as calcium carbonate	115.74	40,495.0
Phosphate	2.62	917.0
Calcium as bicarbonate	162.00	56,700.0
Iron oxide	5.14	1,799.0
Aluminum oxide	1.36	476.0
Magnesium oxide	60.00	21,000.0
Arsenic oxide	1.40	490.0

Data from Beg et al. (1975).

Among the creeks, the most important areas are Korangi, Phitti and Gharo creeks. At present Korangi creek directly receives the effluent from the oil refinery, the Karachi Electric Supply Corporation power house, the soda ash factory, and Indus Chemicals. Apart from storm water drainage discharge from District II, the creek also receives the effluents being discharged through Gizri creek.

To release greater pressure on the present harbor, located in Manora channel, the government has decided to construct a new harbor, port Mohammad Bin Qasim, which is already underway at Gharo. The entrance to the new harbor will be through Phitti creek and Gharo creek. It is expected that the new harbor will be capable of receiving cargoes up to 20,000 tons by 1980, and 75,000 tons by 1985. Close to Gharo at Pipri point, the country's biggest steel mill is under construction and expected to begin operations by 1980, using the creek water for its cooling system. New petrochemical industries are also being developed in this area. Thus, the entire area south and southeast of Karachi (along the northern and northeastern bank of Korangi creek) will be the site of new industrial expansion. This will likely have a drastic effect on the environment of these creeks.

Discharge of Radioactive Substances

The Karachi Nuclear Power Plant (KANUPP) is located on the west coast of Karachi harbor, near Paradise Point, Hawks Bay. The following discharge rates of different radionuclides are shown in Table 3.

Table 3. Release of radionuclides by Karachi Nuclear Power Plant

Radionuclide	Maximum permissible release rate (Ci/sec)	Total released, 1974	Percent of MPRL actually released, 1974
Tritium H3	0.7×10^{-2}	1,066 Ci	1.0%
Noble gases Xe-Kr	0.7×10^{-2}	not detectable	-
Radio-iodines	3.6×10^{-8}	36.07 Ci	0.3%
Particulate activity without Sr-90	1.2×10^{-5}	-	-
Particulate Activity containing Sr-90	1.2×10^{-8}	148.75 m Ci	0.4%

Data from Hasim et al. (1975).

The discharge of radionuclides reported in Table 3 is within the permissible limit recommended by the International Commission on Radiological Protection. Since the tide from Hawks Bay advances eastward, it is expected that any significant change in radionuclide discharge from the nuclear reactor will affect the important food source in the sea. No observation is yet available on contamination of fauna and flora by radionuclides from this region.

Oil

The Manora channel and its vast backwater are affected by oil. In the lower harbor area, oil slicks have been a potential hazard to life in the eastern backwaters. At high tide the water from the lower harbor floods through China Creek into the eastern backwaters, spreading oil and creating potentially hazardous conditions. Accumulation of oil in this backwater has turned the entire basin and embankment of the creek nearly black with oil and its degradation products. At tide the incoming coastal water (average volume of sea water entering the channel is 3.4 million m^3) mixes with oil contaminants of the lower harbor and sewage of the Lyari outfall. As a result, not only is the vast area of channel backwater affected by pollution but also a substantial amount of mixed water is returned to the coastal region.

Information on the nature of pollutants being discharged through the Indus River into the sea is not presently available. In view of greater urbanization along the river's course, it is expected that domestic, agricultural and industrial wastes must be present in considerable quantities. Domestic sewage, however, because of the river's length, probably undergoes decomposition to a large extent. Agricultural use of large quantities of pesticides and industrial effluents discharged through a number of cities into the river both need to be investigated.

PRODUCTIVITY AND FISHERY RESOURCES

Results obtained during the International Indian Ocean Expedition have shown high productivity of the region adjoining the area of Pakistan (Ryther and Menzel, 1965). The values for organic production recorded from the shelf were as high as 30.6–83.3 mg C m^{-3} day^{-1} (Kabanova, 1964) and 1 g C m^{-2} day^{-1} (Ryther et al., 1966). This regional productivity is reported to exceed that reported from other parts of the world oceans (Ryther et al., 1966).

Among the biological resources, shrimp and fish are significant. In Table 4, salient features are given for commercial production of marine fish and shrimp from the Pakistan coast for 1974. The production values are based on statistics provided by the Pakistan Marine Fisheries Department, and the production estimates given here may be considered with certain reservations. First, they represent only the catch statistics with limited fishing capability of fishing fleets. Most of the fishing is done within 5–30 fathom lines. Second, no thorough estimate of the population of exploitable species is yet available nor is the migration pattern of those spending time in the inshore and offshore waters known (Zupanovic, 1972) so that comparison between actual production and present commercial catch is difficult. Zupanovic (1972) calculated the potential yield of demersal fish from the Pakistan coast to be about 5.8 g/m^2, which is higher compared with his quoted values for demersal fish of the North Sea (1.3 g/m^2) and for the bottom fish from Thailand and the Philippines (3.6 g/m^2). The value from the Pakistan coast is slightly lower than that reported from the Thailand Gulf (6.0 g/m^2).

The catch ratio of fish to shrimp suggests that conditions along the Karachi and Sind coasts are ideal for shrimp. Earlier reports on shrimp fisheries of these two coasts and other areas of Pakistan support this (Qureishi, 1949, 1961; Zupanovic, 1972). The total commercial production from the Pakistan coast is valued at 12 million dollars for 1974, of which shrimp account for 11.5 million dollars.

Sharks and rays form a significant portion of the commercial catch, with catfish (*Arius thalassinus*), jewfish (*Johnius coitor*) and Indian shad (*Hilsa ilisha*) forming an important fraction. The shad is a catadromous fish which breeds in the Indus about 500 miles upstream. Since construction of a barrage about 150 miles north of the river confluence, the yield has declined through the years (Qureishi, 1967). Zupanovic (1972) reports more than 90 species which form a noteworthy portion of demersal fishes along the Pakistan coast. His data on fish distribution show that a number of species migrate shoreward, particularly during the southwest monsoon when the cool and deoxygenated water enters the shelf as a result of upwelling, but with recession of deoxygenated water in the shelf in winter and spring (Banse, 1968; Haq, 1968) many species disperse into deeper waters. With larger mechanized boats it was suggested that the demersal fisheries production could be increased to 500,000 metric tons, more than five times the present value.

From what we know of the distribution and migratory behavior of fishes, it appears that a large number of species such as *Dussumieri acuta*, *Thrissocles* sp., *Ilisha* sp. (Clupeidae), and others such as *Sphyraena acutipinnis* (Sphyraenidae), *Lates calcarifer* (Perciformes), and mullet are reported in large schools in the coastal waters, creeks and harbor where they seek shelter particularly during the turbulent conditions of the southwest monsoon (Qureishi, 1961; Zupanovic, 1972). Recently Ali Khan (in press) has found nursery grounds of *Sardinella* sp. near the creeks of the Sind coast. He found larvae mortality at early developmental stages, attributing this to either natural causes or to pollution. He believes that many fish species may have their spawning and nursery grounds in the creeks and vicinity, an aspect which needs to be investigated.

Table 4. Salient features of marine fish and shrimp production in Pakistan, 1974*

Total commercial catch, marine fish and shrimp: 150,010 metric tons

Commercial catch:
Edible: 55.9%
Inedible (fish meal F.P.C., oil and dehydration products, etc.): 44.2%

Distribution of catch (in metric tons):

Area	Fish	Shrimp	Total
Karachi and Sind coasts	94,670	15,500	110,170
Baluchistan coast	39,290	500	39,790

Total number of fishermen: 97,200

Total number of mechanized fishing fleet: 1,867

Trawlers	1,076
Gill-netters	791

Total number of non-mechanized sail boats: 6,330

Total value of products in millions of dollars: 12.0

Shrimp	11.50
Lobster	.30
Fish	.15
Miscellaneous	.05

*Data from Pakistan Marine Fisheries Department.

Shrimp fisheries in Pakistan are represented by 3 important genera, i.e., *Penaeus* (Jhari), *Metapenaeus* (Kairi) and *Parapenaeopsis* (Kiddi). The genus *Solenocera* is represented by less abundant species of no commercial value (Tirmizi, 1972). The species forming the bulk of the shrimp catch are *Penaeus merguiensis*, *P. penicillatus*, *Metapenaeus monoceros*, *M. affinis*, *M. brevicornis* and *Parapenaeopsis stylifera* (Zupanovic, 1971). All other species are less abundant or form only a small fraction of the catch. Almost all breed in coastal waters and their larval stages migrate to inshore creek waters to complete part of their life cycle. *Penaeus stylifera* is the only species which is reported to complete its life cycle in offshore and deeper waters (Mohamed, 1967). Results obtained on shrimp larvae during the past 4 years by H. Hassan (Institute of Marine Biology, Karachi University) and others (Haq and Hassan, in press) suggests the presence of fairly large concentrations of early post-larvae in particular in Korangi creeks. Zupanovic (1971) reported vertical distribution of most species, indicating a migration trend to deeper waters in winter while in summer their large concentrations are present near the surface. These events coincide with the summer monsoon upwelling and recession of deoxygenated water reported earlier. This suggests that their distribution might be closely related to oxygen distribution in the shelf. The above information will clearly indicate the significance of creeks and inshore areas as important habitats, which serve as sheltered areas or spawning and nursery grounds for a number of commercially important species.

The Oyster Fishery

The edible oyster from Sind creeks was once a flourishing industry from 1850-1897 and the specimen used to be sold on demand in many parts of northern India (Hornell, 1910). His data for oyster fisheries are given in Table 5.

Table 5. Oyster fisheries of the Sind and Karachi coasts, 1896-1908, in dozens (from Hornell, 1910)

Years	Indus creek	Manora west backwaters (Mauripur)	Hab River
1896-1898	26,150	--	--
1898-1900	32,600	900	2,300
1900-1902	17,803	340	500
1902-1904	1,750	260	500
1904-1906	13,030	100	3,400
1906-1908	4,930	875	1,100
Total	96,263	2,475	7,800

Hornell (1910) stated that "the Sind oyster is known for excellent flavour, attains a marketable size and fattens rapidly. It is a species which will undoubtedly respond satisfactorily to culture." Of the 72 beds reported by Hornell for the Sind creeks, Ahmad (1971) reports some 8 beds, most of them patchy and the rest probably destroyed by natural factors such as siltation and hydrogen sulfide from sediments. The addition of pollutants in the backwater area of Manora channel and Korangi creek where oysters were found in abundance makes any hope of recovery of this important fishery source a remote possibility unless effective measures are adopted.

EFFECT OF POLLUTION ON MARINE LIFE AND CONTEMPORARY RESEARCH

An adverse environmental change caused by either natural factors or pollution resulting from man's activities may have one of the following effects on an organism. It may (a) succumb to the acute toxicity or stress, (b) tolerate the change but develop chronic or sublethal toxicity leading to impairment and disability of normal physiological processes, or (c) undergo bioaccumulation of pollutants without impairing the normal physiological processes. In the first category, extensive and intensive studies recently carried out clearly demonstrated the vulnerability of organisms to toxicity by a number of pollutants such as oil, heavy metals, pesticides and other organochlorine compounds. Extensive work on the subject has already been published (Ruivo, 1972, and others). Studies on oil slicks following such major incidents as the *Torrey Canyon* disaster, the oil spill at Santa Barbara and spills in other areas have demonstrated that initially oil could be highly toxic and deplete the entire fauna and flora, and the use of detergents may add to the toxicity (Smith, 1968; Straughan, 1972; Blumer and Sass, 1972). Oil is shown to affect the development and growth of fish eggs and larvae (Mironov, 1972). Dispersal of oil through currents and waves may minimize this effect. It has been shown experimentally that many organisms tend to depurate oil and metabolize its products, and very small amounts could be retained by an organism (Battelle, 1973; Lee, 1975). However, in areas where chances of oil dispersal are low, due to peculiar hydrographic regimes it may totally destroy life. Oil contains many insoluble fractions and many forms of carcinogenic material in soluble fraction such as napthalene and pyrobenzens which may be retained in some quantity or transferred to the higher trophic level. The transfer efficiency of such dangerous components and their detoxification mechanism is yet to be satisfactorily studied in the marine food chain.

Heavy metals and pesticides are the most dangerous pollutants because of their stability in the biological system. Heavy metals can combine with protein and petroleum, and halogenated hydrocarbons are concentrated in the lipid components. Vast amounts of published work have established the toxicity of heavy metals to varieties of organisms in the food chain. Of particular importance are the effects of mercury, zinc, copper, cadmium and lead, which are often discharged with sewage into the sea. Many species of phytoplankton develop toxicity or their growth is inhibited in the presence of as low a concentration as .001 to 2.5 ppm (see Table 6) (North et al., 1972). Similarly, a number of zooplankton, when subjected experimentally to heavy metals, show sensitivity to a concentration ranging from .04-4.3 ppm expressed in terms of LC_{50} and TLm_{96} hr, in most cases (Corner and Sparrow, 1957; U.S. EPA, 1974). In addition, recent studies have shown acute toxicity of heavy metals (Portman and Connor, 1968; Portman, 1972; and others). There are also many references in the literature which clearly establish acute toxicity of pesticides such as DDT, dieldrin and many organochlorine compounds to a number of marine organisms (Kneip et al., 1972; North et al., 1972). Numerous observations on chronic and sublethal toxicity of heavy metals, pesticides, organochlorine compounds and oil have shown these to affect growth and reproduction in a number of marine animals (Winter, 1972; Eisler, 1972; Mitrovic, 1972).

One of the most important aspects of the problem is the remarkable capability of the biological system to concentrate heavy metals and pesticides in the body tissues. The concentration factor for copper and mercury in fish and shellfish may reach as high as 100,000 (see Table 7), where it can be hazardous to man. The same is true for pesticide organochlorine and organophosphorous compounds (Table 8) (Kneip et al., 1972). The incidence of "minamata" disease in Japan claimed no less than 100 lives as a result of bioaccumulation of the most poisonous mercury compound, methyl mercury, in the body tissues of edible crabs, oysters and fish (Kurland et al., 1960). "Ciguarta" disease in Hawaii, principally caused by eating a reef fish, is another instance, and both are good examples in this context (Randall, 1958). It has been shown that heavy metals concentrated at lower trophic levels may be transferred through the food chain with 0.1 to 1.0% efficiency (Yoshida et al., 1967). Yet another aspect, ecologically important as well, is the behavioral response of marine animals to low concentrations of these pollutants. It has been demonstrated that Atlantic salmon tend to avoid migration into the northern arm of the Miramichi River in Canada because of polluted environment and waste discharge by area paper mills (Elson et al., 1972). Avoidance reaction to heavy metals is also reported in other fish (Sprague and Drury, 1969). Similarly, shrimp and prawn are reported to be highly susceptible to heavy metals and to avoid an environment polluted with such metals (Cole, 1973). The effects of these metals for a given sublethal concentration may be 100 times more deadly to the larvae than to the adult (Cole, 1973).

Table 6. Concentration of different compounds reported to cause growth-inhibitory toxicity to algae (From North et al., 1972)

Pollutant category	Total metals tested	Algal species tested	Algal type	Inhibitory concentration (mg/ℓ)	Toxic concentration (mg/ℓ)
Heavy metals	10	4	Diatoms	.001-2.5	
Organic pollutant	38	4	Diatoms and flagellates		
Pesticide	17	11	Diatoms, flagellates, seaweed		.001-2.0
Detergent	7	8	Diatoms and flagellates		.5-10.0

Disposal of domestic sewage containing nutrients may be a potential source of fertility and eutrophication of coastal areas (Pearce, 1972; North et al., 1972). On the other hand, dumping of sewage into areas less influenced by coastal hydrographic regimes may cause great biochemical oxygen demand and may result in reduced diversity of fauna or flora and elimination of important species, such as shellfish, or increased pathogenic organisms (Cole, 1973). The best example of the change brought about by sewage is that of Kaneohe Bay, Hawaii, where proliferation of a blue-green algae is shown to have caused elimination of coral reef and development of "ciguarta" disease (Johannes, 1972). Many metals and organic substances are readily bound up with sediments so that in areas of large-scale dumping of waste, the latter material leads to total uptake by the sea bed. Such a situation has a great modifying influence on the community. Many animals preferentially use certain pollutants to the exclusion of others, causing partitioning of such pollutants among the most resistant species (Phelps, 1966).

Table 7. Concentration of some toxic heavy metals by marine organisms*

	Normal concentration in seawater (μg/ℓ)	Concentration factor	Lethal concentration to man (mg)
Antimony	0.5-4.0	300	96
Arsenic	3.0	3,300	130
Cadmium	.02-20	4,500	35
Lead	.03-9	1,400	? (Carcinogenic)
Cobalt	0.3-1.0	21,000	? (Carcinogenic)
Copper	1-20	7,500 (oysters)	100
Mercury	0.03-0.15	100,000 (fish)	? (Impairment of sensory organs)
Zinc	1-20	100,000 Zn^{65} (Shellfish & fish) 32,500	

*Data based on values reported by Goldberg (1965) and Portman (1972).

Table 8. Pesticide residues (DDT metabolites and dieldrin) in Hudson River biota*

Trophic level		Pesticide concentration range (ng/g)	Concentration factor
Water		$0-20 \times 10^{-3}$ ng/ml	-
Plankton		25-150	1,000-7,000
Algae		30-100	1,500-5,000
Bivalves		30-100	1,500-5,000
Some fish	a)	30-100	1,500-5,000
	b)	100-1,000	5,000-50,000
Birds		1,000-3,000	50,000-150,000

*After Kneip et al. (1972).

PROBLEMS INVOLVED IN STUDY OF THE ECOSYSTEM

From the foregoing it is obvious that two major causes affect the coastal environment of Karachi and the Sind coast. Natural factors, such as siltation and aggregation of organic matter in the creek embankments, brought about under the cumulative influence of changing hydrographic regimes over several centuries, have contributed to generation of anaerobic conditions immediately below the surface sediments and the liberation of H_2S in the water. These, coupled with periodic penetration of deoxygenated deep water into the shelf from July to December, subject pelagic as well as intertidal life to great physiological stress. The discharge of industrial and domestic effluents in vast quantities will undoubtedly create more serious problems for the protection and management of coastal and creek environments. If the situation is allowed to continue it will drastically affect the country's important resources.

Such an enigmatic situation poses the question of what criteria and judgment should be exercised toward maintenance of the ecosystem integrity and management of the biological resources. Whether a holistic approach is more appropriate in dealing with the ecosystem, for instance, following the trophic dynamic approach of Lindeman (1942), or a measure which could provide an idea of the functioning of its main parts or "products of interest" (Warren, 1971). Since management cannot await full understanding of the vast diversity of species involved in production, research in some reasonable balance may be directed toward the immediate goal and toward understanding of the fundamental aspects of community patterns and the life cycle and biology of important species.

Suggestions for the Future

1. Considering the regional ecological conditions around Karachi and its adjacent creek system complex, the ecologically defined management region may be more appropriate as an administrative concept in controlling pollution. There are at present three such areas: 1) the polluted backwater zones of Manora Channel; 2) the Korangi, Phitti and Ghara creek complex; and 3) the Indus River area, which also serves as sheltered area, spawning and nursery grounds for varieties of fish and shrimp of great economic value to the country and which could be developed into a complex of mariculture farms.

2. Baseline studies should be established for each ecologically defined management region. Such studies may be divided into two parts, one based on physiological criteria related to principal components of communities in each area of studies, and the other based on ecological criteria related to pollutants being discharged into the area and their impact on community changes.

3. Systematic surveys of fauna and flora should be carried out in the regions, dealing particularly with principal species of each area.

4. a) Physiological criteria should be applied to the baseline studies relating to the effect of pollutants on marine life. Acute toxicity tests should be carried out using standard procedures for principal species and their food organisms. b) Sublethal or chronic toxicity experiments should be undertaken to study long-term changes likely to cause both in terms of production and growth of principal species or "products of interest" as well as their food organisms. Special consideration must be given to the effects of sewage, oil and oil products, heavy metals, and organochlorine compounds on feeding, respiration, reproduction and migration under controlled experimental conditions. Emphasis should be given to the groups of fish, shrimp and their larvae; the latter in particular necessarily spends certain periods of its life cycle burrowed in sand and silt in the creeks. c) Bioassay of pollutant-sensitive organisms and those capable of bioaccumulation of heavy metals, pesticides and organochlorine compounds should be carried out extensively with varieties of organisms constituting the main components at each trophic level. Rates of accumulation at various concentrations coupled with knowledge of

individual species life spans, particularly those commercially exploitable, should provide the basis for monitoring populations of important species. d) As for natural causes, liberation and distribution of hydrogen sulfide should be studied in the creeks. Effects of low oxygen tension on fish and shrimp should be examined experimentally for correlation with observations on distribution in the natural environment.

5. a) Ecological baseline studies initially should include identification and quantification of pollutants being discharged through various sources into the Manora channel region and creeks. To cope with this, facilities for analysing principal pollutants should be established as an adjunct to existing marine laboratories. b) Dispersal rates of pollutants being discharged into the sea in relation to prevalent hydrographic regimes should be studied to develop better understanding of the spread of such pollutants in the coastal belt as well as in the creeks. c) Analysis of pollutants bound between sediments and water interface in areas of sewage disposal, such as Manora breakwater and Korangi creek, may be undertaken and the effect on the organism community should be studied.
d) Changes in the community pattern, both in pelagic and intertidal zones, due to natural causes should be determined separately from those resulting from human activities so that effective measures can be adopted to deal with the two different situations. e) Ecological criteria should be applied to growth of the most resistant species in polluted areas, which may serve as pollution indicators. f) Based on ecological and experimental results on lethal and sublethal effects, water quality criteria should be developed, in consonance with international standards. Effective treatment plants may be added with facilities for efficient removal to cope with large amounts of sewage being discharged into the sea. Already steps are being taken by the Karachi Master Plan Department to increase the number of plants. g) A monitoring system of coastal areas and creeks and of principal animal populations should be developed, for regular checks of water quality.

6. Discharge of pollutants and silt through the Indus River and its possible long-term effect on the communities should be studied to provide effective control of the coastal environment and its biota.

7. The effect of discharge of radionuclides from the Karachi Nuclear Power Plant on the west coast of Karachi and its effect on animal populations should be studied.

8. Steps may be taken by the Government to introduce regulations and act to control effluent discharge by each industry at the source in accordance with international regulations. These may be modified in the light of new findings.

9. Scientific investigations of pollution, because of the sophisticated nature of instrumentation, is often beset with numerous scientific and technological problems in a developing country. Steps should be taken to develop the requisite scientific base using the infrastructure available in the country to cope with increasing problems.

10. In a developing country such as Pakistan, pollution studies could produce desired results if public awareness of the seriousness of the problem is developed through dissemination of information on the environmental hazards caused by pollution, using such media as radio and television.

ACTION TAKEN ON POLLUTION STUDIES AT THE NATIONAL LEVEL

The Government of Pakistan, recognising the importance of all types of pollution on human health and on future resources, has recently established a Man and Biosphere Committee at the national level. The object of this committee is to initiate steps to study various aspects of environmental hazards caused by human activities and to develop measures for controlling future environmental pollution. Steps are being taken to develop research on marine pollution in cooperation with various national agencies such as the Karachi Master Plan Department, Man and Biosphere Committee, Pakistan Council of Scientific and Industrial Research, Institute of Marine Biology, the Biochemistry Department of the University of Karachi, and other agencies at the national level.

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OVERVIEWS ON MARINE POLLUTION IN INDIA

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India is the second most populous and the seventh largest country in the world. It has a coastline of 6,083 km. Marine pollution is associated with the drainage of domestic and industrial wastes directly into coastal waters or indirectly via river waters. India has three major river systems: The Indus and its tributaries in the west, the Ganges and its tributaries in the central and eastern part, and the Brahmaputra system in Assam. They all start in the Himalaya Mountains and receive a steady supply of water from the melting snows and glaciers. The Ganges flows for 2,250 km through flat fields of Bengal where it meets the Brahmaputra in Bangladesh to form a vast delta along the Bay of Bengal. These river valleys are the most crowded sections of the country. They are fertile and their waters are deep and broad enough for river transportation. On the Ganges tributaries are found more of India's villages, its productive irrigated land, and its sprawling industries than anywhere else in India. The Brahmaputra also empties into the Bay of Bengal. There are several other rivers and monsoon rain-fed streams that drain into the Bay of Bengal on the east coast and the Arabian Sea on the west coast. The rainfall brought by the monsoons between June and September, which amounts to more than 80% of India's annual rainfall, causes severe flooding in several areas.

After independence from the British in 1947 India has initiated programs for economic development. India decided in the early 1950's to try to industrialise herself and raise the standard of living with the aid of a series of five-year plans. This organized scheme not only improved industrial development but also other important areas such as agriculture, education, social welfare, etc.

Industrial Development

India's raw material situation is highly favorable for industrial development. India has among the largest known deposits of high-grade iron ore in the world, as well as an enormous supply of coal, and also has the world's second largest reserves of bauxite for aluminum and ample atomic materials such as thorium. With Brasil and the Malagasy Republic, India supplies most of the free world's manganese, four-fifths of the world's mica and also has great hydroelectric potential.

Transport, communications, electric power and steel capacity, which are generally regarded as four of the chief prerequisites for further industrialisation, have developed at a tremendous rate in the past twenty-five years. During this period India's industrial production has tripled.

The only major gap in the industrial resources picture has been petroleum, but even here important reserves have been discovered in recent years. Exploration for petroleum and setting up oil refineries received proper attention only after 1947. For example, production of refined petroleum products of 0.2 million tons in 1950-1951 increased to 18.2 million tons in 1972. The oil and natural gas commissions' efforts yielded further increases in production, as well as discovery of new offshore drilling sites for oil. Among the new sites, commercial production of oil from the first two of Bombay High Wells (West Coast) was scheduled to begin in April 1976. Actual production by the end of 1976 is expected to be 0.5 million tons, but the rate of production would be gradually increased to 1.5 to 2 million tons by year's end.

Although there has been considerable development of large-scale industries during the 25 years of planned development, India still remains predominantly a country of village and small industries. The number of workers engaged in handloom industries is greater than the number employed by organised industries and mining industries combined. Village industries are generally of traditional nature catering primarily to local markets.

Use of Insecticides

Public Health

Insecticides have produced enormous benefits for the inhabitants of India in that they have assisted in bringing malaria under control and have helped in other ways to reduce illness which had sapped the vitality of a substantial portion of the population. It has been suggested that no other single discovery has done so much for public health in developing areas as has been accomplished by DDT.

Agriculture

Agriculture is still the chief industry in India accounting for almost half the national income and serving as the means of livelihood for more than 70% of the working population. Concomitant with the application of fertilizers, the use of DDT and related insecticides produced an upheaval in agricultural output. New strains of food crops, notably wheat and rice, have multiplied many-fold the amounts that can be produced in a given area with a given supply of labor. But the success of "green revolution," too, depends vitally on the availability of insecticides.

However, DDT is a long-lasting pollutant. As these insecticides accumulate in the soil, food and in the human body, in the long run their use may be a very mixed blessing. For these very reasons, more developed countries decided to limit or outlaw the use of some of the dangerous chemical sprays. However, they cannot protect themselves from the importation of these pollutants. As we know, DDT and other insecticides are spread rapidly across the globe by air and water currents. A good example is seen in that a certain type of DDT sprayed on crops in East Africa was found and identified months later in the Bay of Bengal, over 6,400 km away (Heyerdahl, 1973). Thus, the insecticide residues in the Bay of Bengal are not merely from Indian sources. Furthermore, insecticides are likely to accumulate in food products. If Arctic mammals are taking in and retaining observable quantities of these chemicals, there is no reason to expect other areas of the world to be immune.

The preceding considerations pose a dilemma for the developed as well as developing countries. Replacement of organochlorine pesticides are essential not only because of their threat to the environment but also because insects have now evolved resistant strains. The criteria for these replacements are that they should be absolutely specific to the undesirable species and nontoxic to other forms of life. There are several fields where this research and development are being carried out. One of the most promising is that of so-called biological control. The World Health Organization and the Indian Government are applying the technique of hybrid sterility in a campaign to eliminate culicine mosquito; the results appear to be encouraging. Another alternative pest control device may be to use insect hormones and their analogs. Although these are currently available for limited use in some of the developed countries, and field-tested in some South American countries, their potential for use on a large-scale agricultural operation in terms of cost effectiveness and environmental impact are yet to be fully understood.

Population Problems--Family Planning Program

In weighing the interests of the developing countries it would be interesting to recall the statement of Dr. Norman Borlaug when he was awarded the Nobel Prize for his contributions to the "green revolution." He used that occasion to point out that with current rates of population increase his achievement was all too likely to prove transitory. With continued explosion in the magnitude of the world's population, any improvement in public health or agricultural productivity may simply result in further population growth. In short, as long as the world does not become serious about birth control, or does not find ways of limiting its population growth effectively, there is some ground for questioning the rationality of chemical manipulations that pose a long-term threat to the human environment. Recognition of this problem and taking preventive measures by implementing family planning programs (since 1952) are indicative of India's commitment to an organized socio-economic development. A full-fledged Department of Family Planning was created in 1966 in the Ministry of Health, Family Planning and Urban Development. The family planning program aims at reducing the birth rate from about 39 per thousand in 1969 to 25 per thousand by 1980-1981. The operational goals are adoption of family planning by the people as a way of life through group acceptance of a small family norm, personal knowledge of family planning methods and ready availability of supplies and professional services.

Current Reports on Marine Pollution

I shall discuss two representative cases; the first one deals with pollution in Visakhapatnam Harbor and the second relates to oil pollution due to transportation mishap. There are two reasons for selecting Visakhapatnam Harbor: (a) as a graduate student and research scholar I have worked at Andhra University, Visakhapatnam, for six years and therefore have a strong interest in the area and (b) published reports on pollution are available.

Ganapati and Raman (1973a, b), on a project entitled "Eco-biology of littoral life in relation to marine pollution," sponsored by the Indian

National Science Academy, found a high incidence of industrial and domestic pollution in the ambient waters of the Visakhapatnam Harbor. Visakhapatnam has a natural harbor, located on the east coast of India, halfway between Madras and Calcutta. The topographical features of the harbor include a narrow entrance channel, and four navigable arms radiating from a central turning basin. These navigable arms providing berthing facilities for the ships are the Western Arm, the Northwestern Arm, the Northern Arm and the Southern Lighter Channel. In recent years many industrial installations have sprung up in the environs of the harbor. From the point of pollution, the most notable are: the Caltex Oil Refinery, the Coromandel Fertilisers, the Hindustan Polymers and the Ore Handling Project. The Caltex Oil Refinery and the Coromandel Fertilisers discharge their effluents into a monsoon-fed stream which in turn opens into the North-West arm of the harbor. The other important sources are from the oil and the ore jetties located in the west and north arm, respectively. Appreciable quantities of oil and ore dust are spilled into the harbor waters during loading and unloading operations. The town's sewage system empties its domestic wastes into the Southern Lighter Channel. In this area, conditions are practically anoxic for marine life due to accumulation of as much as 6% organic carbon in the substrate and emanation of hydrogen sulphide (Ganapati and Raman, 1973a). While the effect of the discharge of industrial wastes in the other arms of the harbor is not so immediately obvious, there are clear indications that the cumulative effect of continuous discharge of the industrial effluents may affect the ecosystem and marine life of not only the harbor waters but also of the nearshore littoral region.

Associated with an increased oil exploration, drilling and transportation, oil pollution on Indian coasts has been an increasingly severe threat for the last few years. On June 18, 1973, the oil tanker M/T *Cosmos Pioneer* was ruptured, releasing 18,000 tons of L.D.O. (black oil) in Gujarat coastal waters (near Porbandar, west coast of India). At that time the Arabian Sea of Porbandar Coast was very stormy due to prevailing southwest monsoon. Ramamurthy (1974) reported on the effects of this oil pollution on intertidal fauna and flora of Gujarat coast. The gradual destruction of major coastal marine communities is probably being duplicated along the northwest coast of India.

Environmental Planning--Pollution Related Research

In order to bring about greater coherence and coordination in environmental programs and policies and to integrate environmental concern in the process of planning for economic development as well as for science and technology, a national Committee on Environmental Planning and Coordination was set up in 1972. This committee was to make recommendations to the Government on all aspects of environmental conservation and improvement. It was entrusted with the development of a major research program in ecology and environment under the UNESCO program, "Man and Biosphere."

India's participation in the conference on human environment at Stockholm in June 1972 was noteworthy insofar as India emerged as a developing nation with a mature environmental policy of its own.

Marine biological research is being carried out at several of the Indian universities, private research laboratories, Central Marine Fisheries research laboratories, Zoological Survey of India and the National Institute of Oceanography. These laboratories are also evaluating the impacts of pollution on the marine environment.

Harmful effects of industrial toxins on skin, blood, gastrointestinal tract, central nervous system and bones are being studied in the Industrial Toxicology Research Centre, Lucknow, to develop preventive measures.

As pointed out earlier, flooding during the monsoon period may affect the marine environment. Since the National Flood Control Program was launched in 1954, significant progress has been made toward the protection of flood-prone areas. The Anti-Erosion Program is taking measures to prevent erosion along the seacoast of India.

The National Water Supply and Sanitation Program was begun in 1954 as part of the health plan to assist the states in their urban and rural water supply and sanitation facilities. Sewage disposal and treatment plants are being built in increasing numbers in recent years.

Conclusions

Since independence, India has launched and is making significant progress in programs for socio-economic development. Associated with the progress in industrial development and exploration of new energy reserves and pest control, there is evidence of environmental pollution. The belief that environmental disruption affects less developed countries in a lesser way is not well founded. Highly industrial pockets and overpopulated towns exist in the coastal areas, where marine pollution phenomena often appear with unparalleled intensity unless adequate preventive measures are adopted. Pollution is certainly a symptom of modernity which comes well in advance of other more desirable features of industrialization. Therefore, developing countries such as India have more opportunity to operate on a preventive basis than developed countries.

Acknowledgments

I thank Mr. Paul Hamilton and Dr. K. Radhakrishna for their help in the literature search. I would like to express my appreciation to Dr. Norman L. Richards, Gulf Breeze Environmental Research Laboratory, EPA, for the invitation to participate in this symposium as a discussant and to present this informal overview.

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RESEARCH NEEDS CONCERNING POLLUTION OF THE MARINE BENTHOS

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INTRODUCTION

This report identifies several research problems on the effects of pollution on the structure of macrobenthic communities. Research needs are divided into two categories: 1) those associated with the development of methods for assessing the "health" of benthic ecosystems, and 2) those resulting from a lack of fundamental information concerning the relationship between community structure and pollutional stress. Obviously, these research areas are closely related and individual projects can make contributions to both.

RESEARCH NEEDS

Methods in Benthic Ecology

The Environmental Protection Agency, Bureau of Land Management, National Oceanographic and Atmospheric Administration, Corps of Engineers, and a variety of other institutions are engaged in major benthic surveys of virtually every biogeographical province of the United States. Each project has "applied" significance either in terms of an immediate problem such as sewage and dredge spoil disposal or in terms of a long-term baseline to detect future deterioration of marine resources. The ultimate value of these surveys to regulatory agencies such as EPA depends on the adequacy of the methods through which the benthic samples are collected, processed, and analyzed. For comparative study it would be desirable for standard methods to be used in all surveys. However, benthic ecologists must design their investigations to meet the requirements of unique objectives and field conditions. Thus, standardization of methods could be counterproductive, but improved guidelines for rigorous sampling designs and statistical analyses which can be adapted to particular situations are urgently needed. Methodological problems that merit special study include: 1) sample size and replication, 2) spatial-temporal distribution of stations, 3) taxonomy of benthic organisms, and 4) biological indices of community structure.

Sample Size and Replication. In many benthic surveys only a single sample is taken at each station, or if more than one are collected, the data are pooled before statistical analysis. Both procedures do not permit analysis of significant differences between stations. Sample size and the number of replicates at each station must be determined on the basis of the microspatial distribution patterns of the assemblage. Most benthic species are contagiously distributed on the bottom. Sampling designs and data analyses obviously will be biased if random distributions are assumed. Fager has shown that rarefaction techniques for estimating species richness will produce major errors if contagious distributions are assumed to be random. Unfortunately, our knowledge of the microspatial distribution of benthic organisms, especially those on the continental shelf, is poor. Quantitative analyses of within habitat species distributions should be conducted to provide an objective basis for the design of larger scale surveys.

Spatial-Temporal Distribution of Stations. The temporal pattern of collections must reflect diurnal, seasonal, and annual variations in community structure. These variations are poorly understood. The possibility of diurnal changes usually is ignored. Surveys seldom last more than a year and assessment of annual variations is impossible. Sampling is often repeated quarterly in an attempt to document seasonal patterns, but it is not improbable that critical periods of larval settling, growth, reproduction, and migration are missed. The temporal design of surveys may differ with habitat. For example, our data on the New York Bight benthos suggest that annual variations exceed seasonal changes, while the reverse may be true for inshore waters. Fundamental knowledge of the temporal patterns of benthic communities must be improved before surveys can be designed to discriminate natural temporal variability from changes caused by pollution abatement or stress.

Problems in determining the spatial distribution of stations are even more complex. Station positions must be stratified to reflect both natural abiotic environmental gradients and pollutional gradients. At a minimum, sediment composition, salinity, temperature, water depth, and vertical relief in the intertidal zone should be determined before biological stations are stratified. Direct observations or predictions from mathematical models of pollutant gradients are also essential. Random sampling within strata may be necessary for baseline inventories of benthic resources, but logistical considerations prohibit such a procedure on a large geographic scale. Alternatively, a restricted number of sampling areas which represent dominant habitat types could be examined quantitatively and the results extrapolated to points of future concern. Straight line transects through well defined areas of stress such as dump sites may be sufficient to document the degree of ecological alteration.

The concept of an experimental control is difficult to apply in field investigations. Use of a temporal control in studies of the benthos before and after pollution is initiated requires a very exact knowledge of long-term variability. A spatial control which differs from a stressed site only in the absence of pollution is very difficult to establish with certainty. Sometimes the degree of impact can be assessed by comparison of conditions along a pollutional gradient which does not include an unstressed control site.

Criteria for locating stations must receive more attention. Preliminary cruises should be designed simply to determine the position of future stations. Justifications for sampling grids should be included in all research reports.

Taxonomy of Benthic Organisms. Accurate species identifications are essential for community structure analysis. Unfortunately, adequate keys do not exist for all taxa found even in many of the best known coastal areas of the United States. Increased support for basic taxonomic research is the only solution to this problem.

The paucity of trained taxonomists forces many projects to develop their own identification capabilities. It may take as long as a year before a novice can confidently identify a polychaete or amphipod to the species level. This learning process can be greatly accelerated if experienced benthic ecologists make reference collections available to those with little prior experience in the taxonomy of the benthos.

Biological Indices of Community Structure. A multitude of faunal density, diversity, richness, dominance, and heterogeneity indices have been applied in pollution research. The ecological significance of many of these indices is obscure. Certainly no single index, especially the information-theoretical measure of diversity, H', can provide an adequate assessment of all aspects of community structure. Appropriate indices can only be identified through comparative study of structural changes in a variety of benthic, planktonic, and nektonic assemblages subjected to different forms of pollution in different biogeographical provinces.

As an example of some of the problems associated with structural analysis, I will describe temporal changes in the density, diversity and heterogeneity of a polychaete assemblage in an area of the New York Bight south of Fire Island, New York. Shannon's index of diversity (H'), Simpson's index of dominance, estimates of areal and numerical species richness, and an index of temporal dissimilarity in species composition and density were calculated for ten polychaete collections made at quarterly intervals from December 1972 to February 1975 (Tables 1 and 2, Fig. 1-4).

Table 1. Indices

Density: $N/0.25\ m^2$

Shannon Index: $H' = \frac{1}{N_O}\left(N_O \log N_O - \sum_{i=1}^{Sp} n_i \log n_i\right)$

Simpson's Index: $1 - S.I. = 1 - \sum_{i=1}^{Sp} \frac{n_i(n_i-1)}{N_O(N_O-1)}$

Species Richness: $S_R = S_O - \sum_{i=1}^{Sp} \log^{-1} \left((\log(N_O-n_i)! - \log(N_O-n_i-N_R)!)\right.$

$\left. - (\log N_O! - \log(N_O-N_R)!)\right)$

Numerical Richness: $N_R = 75$

Areal Richness: $N_R = N/0.25\ m^2$

Table 3. Temporal patterns of polychaete species diversity and density at Station A, 23 km south of Fire Island, New York

	Cruise Date and Number									
	Oct 72 1	Feb 73 2	May 73 3	Aug 73 4	Nov 73 5	Feb 74 6	May 74 7	Aug 74 8	Oct 74 9	Feb 75 10
Density (N/0.25 m²):										
Spiophanes bombyx	1	1	10	206	101	125	180	103	2	1
All Polychaetes	60	38	60	292	212	277	337	167	159	56
All Polychaetes less S. bombyx	59	37	50	86	110	152	157	64	157	55
Diversity:										
H'	.85	.88	.85	.51	.61	.57	.53	.51	.76	.71
1 - Simpson's Index	.78	.81	.77	.49	.60	.53	.50	.59	.72	.67
Species Richness:										
Sg(N=75) Numerical Richness	11.6	15.0	13.6	9.0	9.8	7.9	9.0	9.9	12.5	11.1
Sg(0.25 m²) Areal Richness	12.6	11.0	12.7	16.0	14.1	12.8	11.0	14.0	17.4	10.1

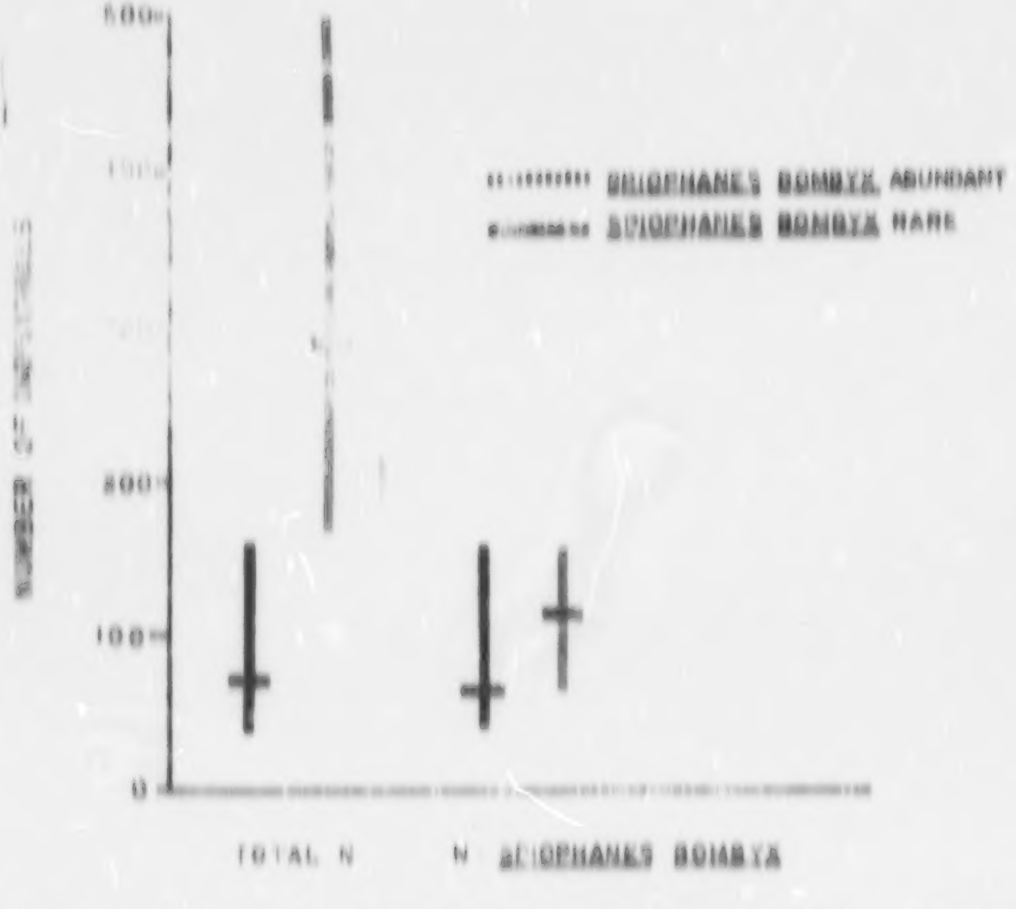

Figure 1. Polychaete density during surveys in which *Spiophanes bombyx* was either rare or abundant

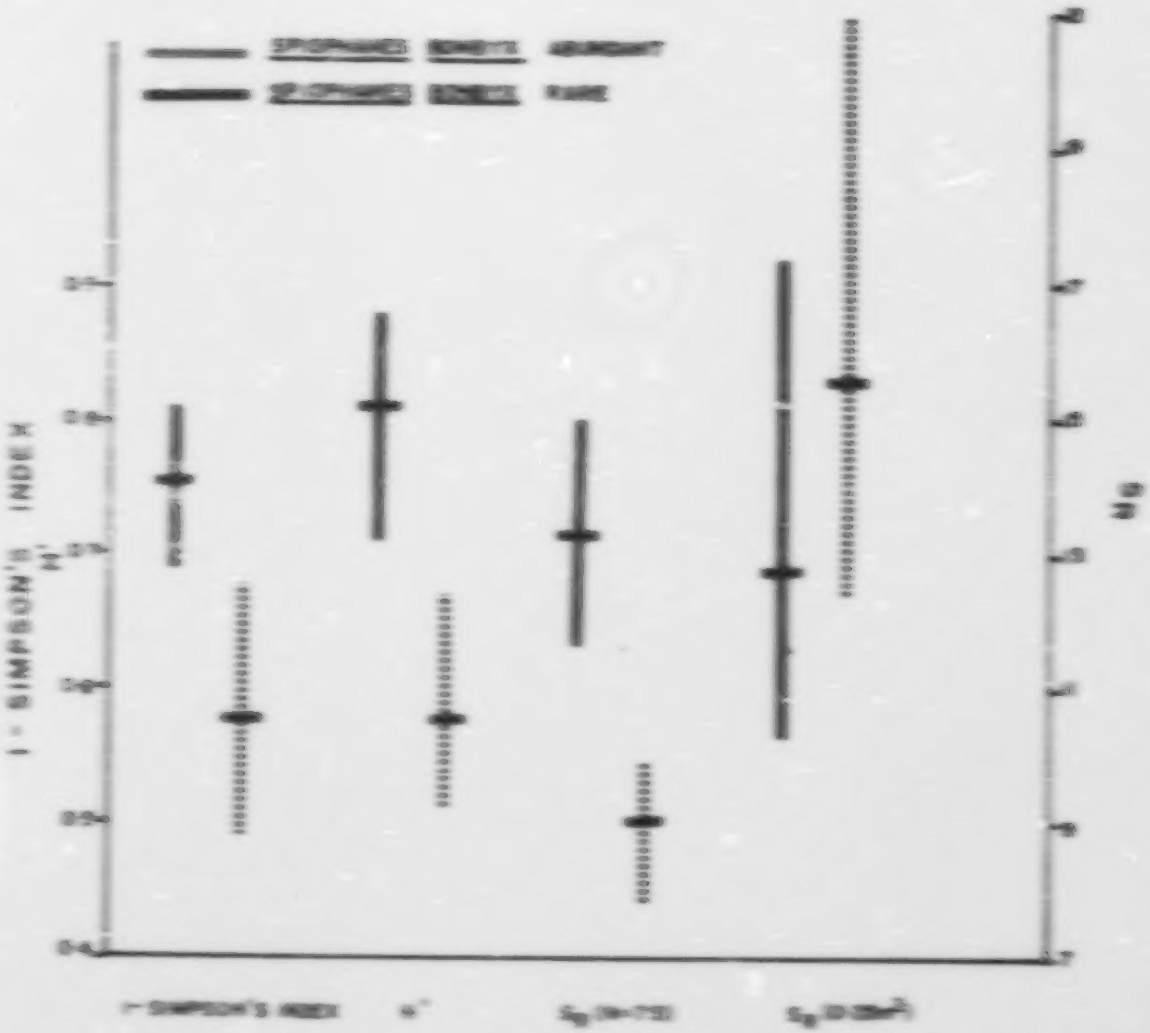

Figure 2. Polychaete diversity during surveys in which Spiophanes bombyx was either rare or abundant

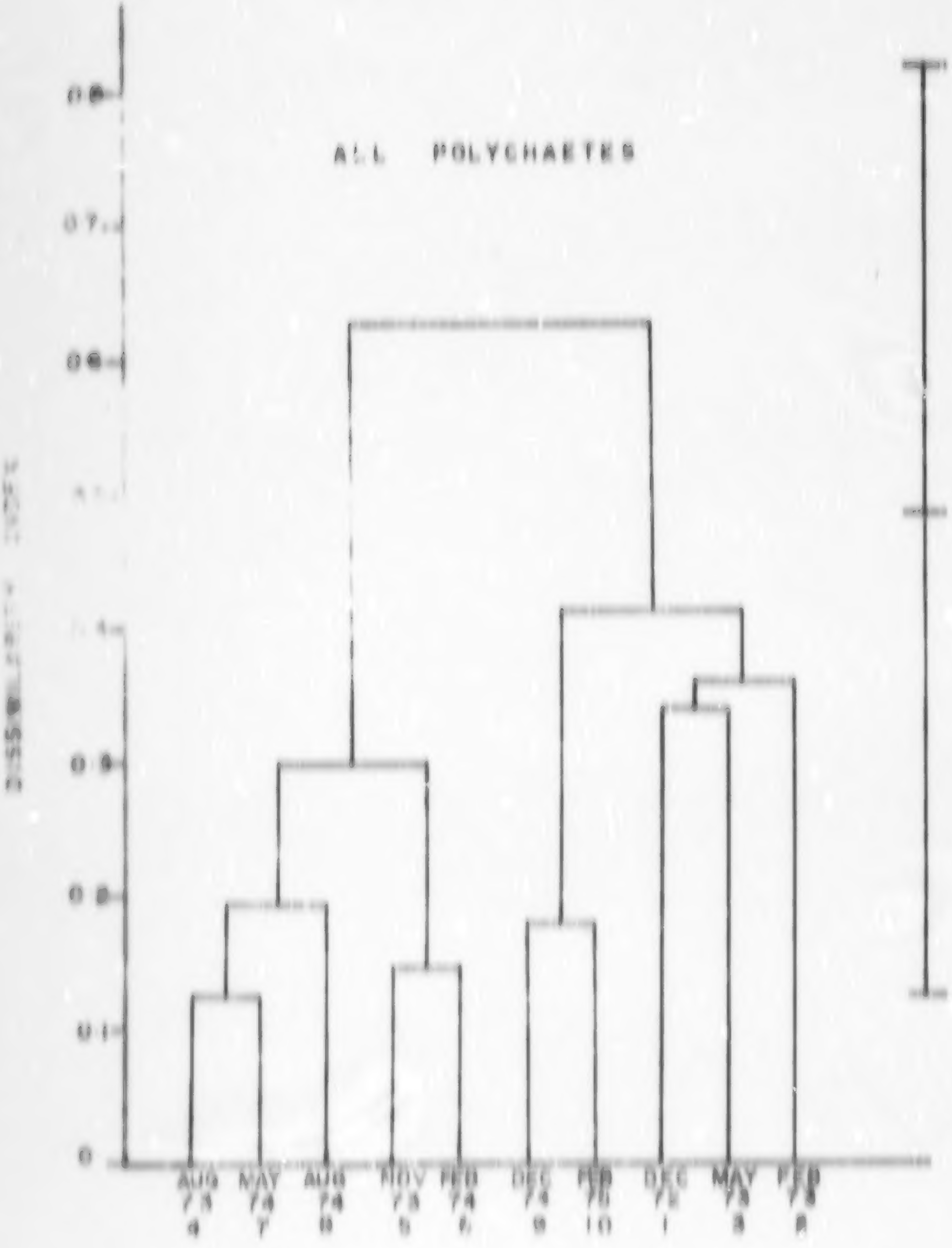

Figure 1. Temporal clustering of polychaete collections including *Spiophanes bombyx*

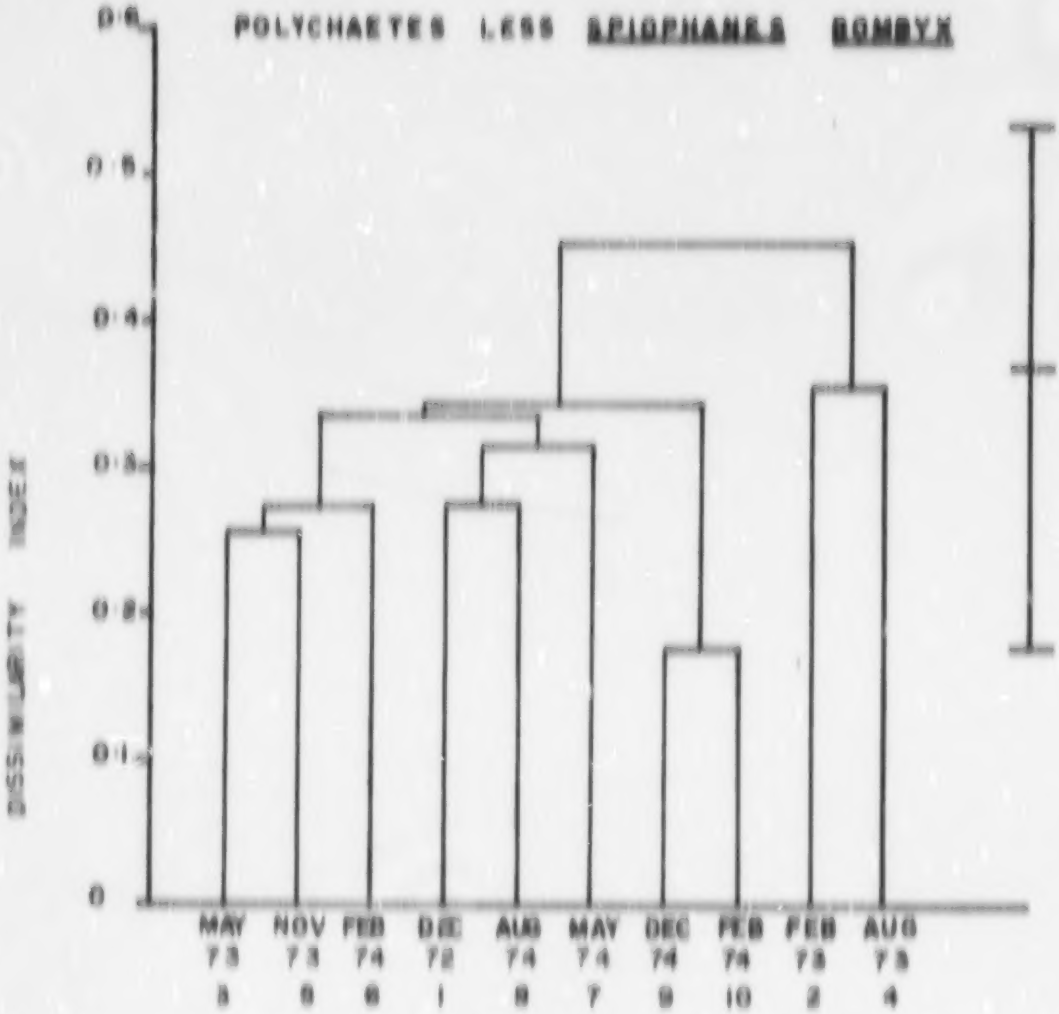

Figure 4. Temporal clustering of polychaete collections excluding *Spiophanes bombyx*

There was a very clear temporal pattern in diversity. H' was reduced from August 1973 through August 1974. In the absence of any other biological analysis, it might be concluded that the condition of the polychaete assemblage had deteriorated during this period. If some form of pollutional stress were present, one might suspect that it was a causal factor. Dominance concentration and numerical species richness followed the same pattern as H'. However, areal species richness increased during the August 1973-August 1974 period. Thus, the two "components" of diversity, richness and dominance, did not follow the same pattern. Values of H', which is supposedly sensitive to both richness and dominance, were most highly correlated with dominance concentration.

These structural changes are due in large part to the appearance after the third cruise of the polychaete *Spiophanes bombyx* in very high densities. The increase in the abundance of *Spiophanes* closely resembles the behavior of opportunistic species such as *Capitella capitata* in polluted environments. However, the appearance of *Spiophanes* was not correlated with any major decline in the density, species composition, or areal species richness of the remainder of the polychaete assemblage as is often found when *Capitella* becomes very abundant. The stability of the assemblage is indicated by the clustering analysis used to describe temporal heterogeneity. When data for all species are classified, two well defined clusters appear in the dendrogram and they represent samples in which *Spiophanes* was either abundant or rare. If the data for all species except *Spiophanes* are classified, there are no distinct clusters, and collections do not group together in any temporal sequence. The relatively low mean dissimilarity index of 0.37 suggests that the species composition and relative abundance of all species except *Spiophanes* did not change greatly during the entire sampling period.

The population explosion of *Spiophanes* had little impact on other polychaetes at this station. The decrease in H' did not reflect a change characteristic of the entire assemblage. Total reliance on this single index would have resulted in a misinterpretation of the data. However, diversity indices should not be totally ignored, but rather applied as an important part of a more comprehensive analysis. Additional research is needed to identify structural parameters which are most useful in pollution research.

Pollution and the Structure of Benthic Communities

Many segments of the marine environment are subjected to multiple stresses from a variety of natural and pollutional sources. A significant advantage of field investigations is that community structure reflects the cumulative effects of all of these stresses. At the same time, it is often difficult to ascribe structural changes to the effects of specific pollutants. Need for a closer coordination between laboratory and field investigations is thus evident. Laboratory experiments with multispecies microcosms should be designed to assess the interaction between stresses. Field surveys must provide the data necessary to establish correlations between biotic and abiotic conditions.

Perhaps the most critical research need concerns the stability of benthic communities. Natural spatial-temporal variations in undisturbed environments must be understood before subtle effects of pollution can be detected. It is hoped that the long-term baseline studies which are currently being conducted in our coastal waters will provide the data necessary for this assessment. We should take advantage of every opportunity to investigate the stability of the benthos when pollution is initiated, increased or abated. Knowledge of assimilative capacities, degradation and recovery rates is very limited. Structural changes cannot always be equated with a deterioration of resources. Succession of eurytolerant species in areas of moderate stress may result in a decrease in diversity, but an increase in stability. Such perturbations may be acceptable if productivity is not adversely affected.

There are several more specific research problems of immediate concern to the EPA marine program in Corvallis. Effluent criteria for chemical toxicants such as trace metals are often based on bioassays with nektonic, planktonic or occasionally epibenthic species. The degree of protection they afford for infaunal species which are in constant contact with contaminated sediments should be examined in more detail. The acute dramatic impact of oil spills in the intertidal zone has received much attention, but chronic effects on subtidal bottom communities is less well known. The degree of treatment of sewage wastes necessary to protect benthic ecosystems is a subject of considerable controversy. If sewage sludge can be used as an agricultural or maricultural fertilizer, can it be applied with beneficial effect to natural marine assemblages? Finally, we must develop bioassays which will accurately indicate the toxicity of dredged materials to coastal benthic communities found in the vicinity of spoil disposal sites.

HYDROLOGICAL, CHEMICAL AND PHYSICAL PROCESSES AFFECTING POLLUTION OF THE BALTIC SEA

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The Maritime Branch of the Institute of Meteorology and Water Management in 1974 undertook a research project on "Hydrological, Chemical and Physical Processes Affecting Pollution of the Baltic Sea," sponsored by the U.S. Environmental Protection Agency (project 05,532-13). Dr. Donald Baumgartner of the Northwest Pacific Environmental Research Laboratory, Corvallis, Oregon, is the Project Officer of this program.

The Gdańsk Basin, located between 54°20'-55°30'N and 18°30'-20°E was chosen as the principal study area (Fig. 1). This relatively small region of 19,000 km^2, constituting 5% of the Baltic Sea area, is under direct influence of the Vistula River, the largest of the Baltic rivers; its contribution amounts to 7% of the total river discharges. Its catchment area of about 195,000 km^2 covers 62% of the territory of Poland. Cities at the Gulf of Gdańsk have about one million population; these are the "Three-Towns" of Gdańsk, Gdynia and Sopot, with a population of 700,000. A complex of shipbuilding, metal and electrical engineering, oil refinery, chemical and food industries exists, all being developed intensively.

The Gdańsk Basin, which includes a typical estuary (the Gulf of Gdańsk) and a part of the open sea, is covered by a network of stations for standard oceanographic measurements. Of the 40 hydrographic stations, about 30 have an extended chemical investigation program. If necessary, for instance, when so-called synoptic measurements are performed, the standard network is multiplied, first of all in the mouth of the Vistula foreground. Further, two shore-based stations have been established for air pollution studies, one in Gdynia and the other in the Hel Peninsula, which extends as far as the central Gdańsk Gulf.

From a hydrological point of view, the Gdańsk Basin--which includes the large river estuary, the shallow coastal area and the Gdańsk Deep (a 100-m depression)--can be considered representative of Baltic Sea conditions, at least for its south central part. Due to its hydrological and topographical features, it can to some degree be considered a simplified model of the entire Baltic Sea in its upper dominant water masses. This can be presented by means of a schematic relationship between the isohaline and the deep water volume existing in the entire Baltic Sea and in one of the sections of the Gdańsk Basin (Fig. 2).

As a result of the specific hydrological regime, connected with highly restricted rate of water exchange between the ocean and the Baltic Sea, two types of water areas can be distinguished: (1) the shallow regions with homogeneous salinity distribution from the surface to the bottom with convection taking place in the entire water column and (2) the deeper regions with strongly variable salinity in the vertical profile with convection reaching only as far as the halocline. This second type, the predominant part of the Baltic Sea, is therefore naturally divided

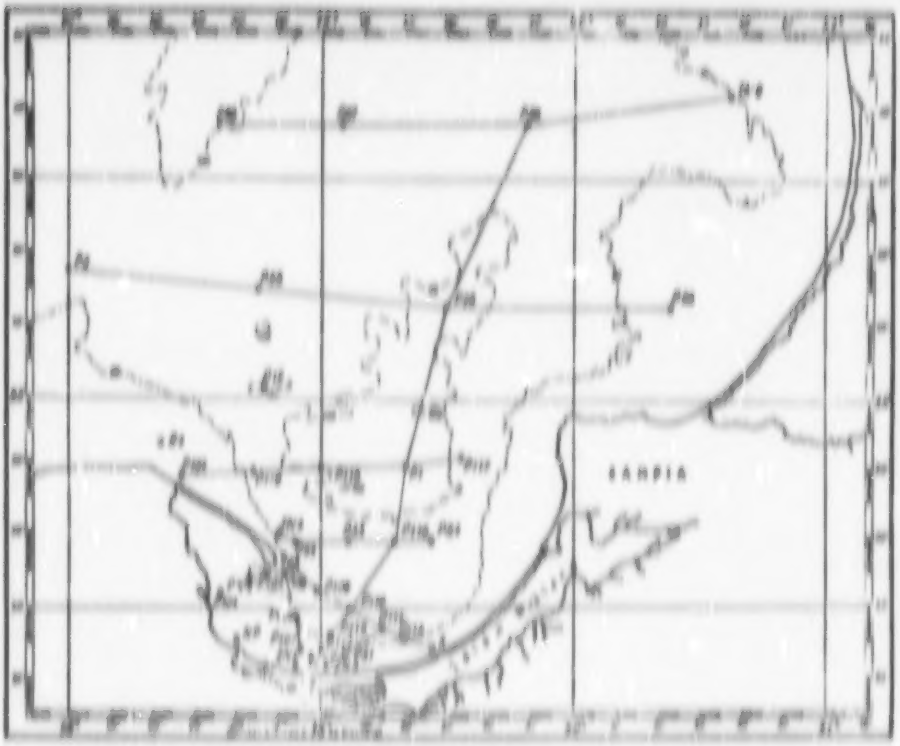

Figure 1. Network of stations in the Gdańsk Basin

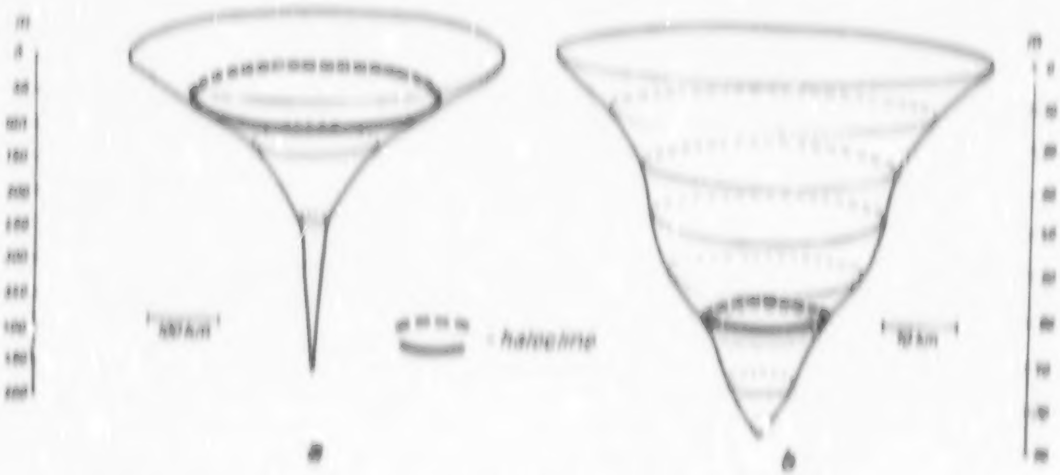
m
0
halocline
m
a
b

Figure 2. Simplified topographic model of a) entire Baltic Sea (Sjöberg et al., 1972) and b) Gdańsk Basin section

into two environments with very cumplex, though restricted interactions. The general features of the Baltic water structure, briefly presented here, have a decisive influence on pollutant circulation in the sea.

The objectives of the Gdańsk Basin study program involve two types of water constituents: (1) compounds closely related to the eutrophication process, such as nutrients, organic phosphorus, organic nitrogen and oxygen, and (2) noxious substances, such as chlorinated hydrocarbons and heavy metals. Together with the hydrochemical investigations two other research directions are considered. The influence of atmosphere on water contamination has been studied by Dr. C. Garbalewski and his coworkers. Water circulation patterns and their verification by means of chemical data is the task of the group headed by Dr. Z. Kowalik. Isolines of mass transport functions, calculated from the preliminary hydrodynamic-numerical model, assuming a one-layer water structure as well as stationary weather and current conditions, are shown in Figure 3 for easterly and westerly winds of 10 m/sec velocity, prevailing in the region under consideration. Calculations of a baroclinic model of water circulation in the Gdańsk Basin are well advanced.

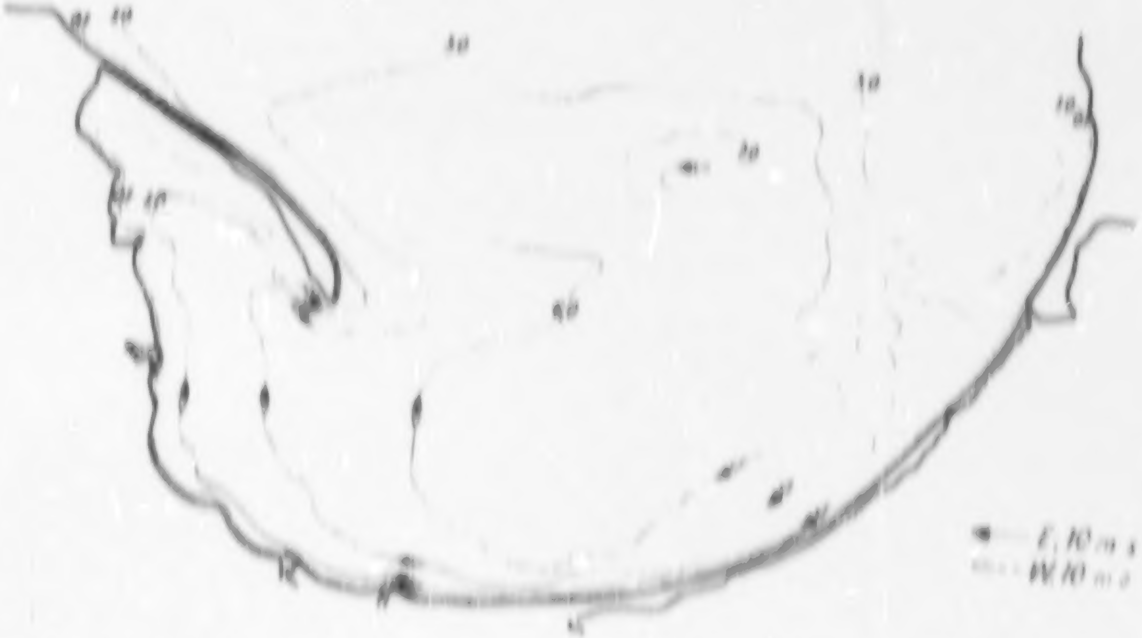

Figure 3. Isolines of mass transport in the Gulf of Gdańsk (flow values in 10^{4} tons/sec)

The eutrophication process is among those phenomena highly dangerous for the Baltic Sea, as far as life conditions are concerned. The Baltic is a typical example of a marine environment where some revaluation in the range of individual ecological factors exists as a consequence of its hydrological regime. Because of heavy runoff, the Baltic phytoplankton contain carbon dioxide, silicates and trace elements in abundance. In the case of nitrogen and phosphorus compounds both sources are essential: the internal (mineralisation and nutrient circulation) and the external (rivers and atmosphere). Thus, oxygen as an element of both respiration and mineralisation processes becomes the factor which controls favorable life conditions on all trophic levels. The main features of contemporary formation of oxygen conditions in the Baltic have been known since the beginning of this century. They demonstrate the gradually progressing oxygen deficit in all parts of the sea, particularly in the northern Baltic. To retain stability in nutrient circulation, nutrient supply to the isohaline water layer, well-oxygenated and comprising the productive zone, should take place from their internal regeneration to the maximal level. Otherwise, the accumulation of organic matter under the pycnocline, together with scarce and non-rhythmical oxygen supply, eventually will result in disappearance of nitrates due to denitrification and in poisoning of the environment by hydrogen sulphide due to sulphate reduction. The total redox reactants system, $PO_4 = f(AOU, NH_4^+, S^{2-})$, is to some extent different in different parts and zones of the sea (Fig. 4), according to whether they have conditions more or less conducive for oxygen supply. Additionally, the strong reducing properties of hydrogen sulphide cause large amounts of phosphates to transfer from the bottom sediments into the solution and enter the phosphorus cycle (Fig. 5). As was proven from examination of sediment cores, the occurrence of hydrogen sulphide in the Baltic is not a new problem; the intensity of this phenomenon, its progressing frequency and spatial extent have been burgeoning for the last 20 years.

The above-mentioned factors cause serious disturbances in the Baltic Sea regarding nutrient circulation patterns. Briefly, this alteration consists of the preponderance of external, anthropogenic sources over the internal ones in supplying the productive water layer with basic nutrients. All of the Baltic Sea regions are to some extent affected by this process, stimulated by a universal trend to widen the application of nitrogen and phosphorus compounds in many fields of human activity. Estuaries, however, are the most affected areas (Fig. 6). Thus, prediction of harmful symptoms is possible unless they occur on a large scale. Even more incomplete and rough is our knowledge regarding the pollution level and fate of noxious substances (stressors) in the Baltic Sea.

Results obtained during the first year of study are sufficient to consider the Gdańsk Basin as polluted with DDT compounds to some extent. There was noticeable correlation between their concentration and distance from shoreline, marked in the mean values calculated for the surface layer of individual regions. The mean concentration of DDT in the inner part of the Gdańsk Gulf amounted to approximately 2 ng/liter and was more than twice as high as for the outer part. No essential differences were found between the outer Gulf and the open sea.

This suggests that in spite of the ban on DDT use in all Baltic countries (in Poland in 1972) some amounts of this very persistent compound still remaining in soil are washed out by rainfall, especially during the last year. In consequence, the pesticides still enter the Baltic Sea via rivers. On the basis of very few determinations of atmospheric precipitations it can be assumed that currently the atmosphere has lost some of its influence as a source of DDT pollution, although possibly some amount of this compound is carried by terrigenous dusts.

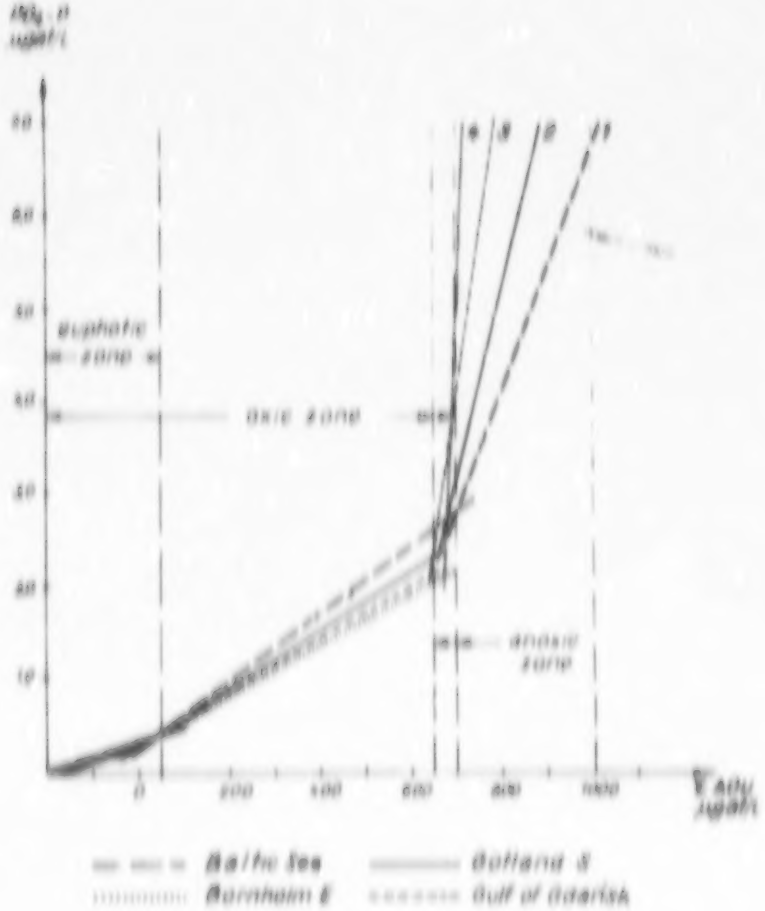

Figure 4. Empirical equations calculated for the relationship of phosphate concentration versus apparent utilization of oxygen, dissolved and originated from nitrate and sulphate reduction (Σ AOU) in different regions of the Baltic Sea, 1969-1973

Because of the bioaccumulation process, the content of DDT, DDE and DDD in benthic organisms was as a rule several orders higher than in sea water. Despite more intense concentration of all these compounds by shellfish (0.06-0.49 µg/g of wet tissue), molluscs (0.04-0.24 µg/g of wet tissue) seem to be better indicators for tracing water contamination. This is correlated with their sedentary character and widespread existence in the Baltic. Some regional variations can be noticed in the DDT level in the benthos. Swedish and Polish data for 1970-72 showed concentration of DDT in *Mytilus edulis* as averaging 0.08 µg/g of wet tissue in the Sound, 0.07 µg/g of wet tissue in the Southern Baltic and 0.04 µg/g of wet tissue in the Stockholm Archipelago waters.

The mean concentration of total mercury in the surface layer of the Gdańsk Basin, calculated for a 15-month period during 1974-75, amounts to 1.2 µg/liter. Mean monthly values oscillated from 0.1 to 2.2 µg/liter. Variations in time did not demonstrate any seasonal character (Fig. 7);

however, the upward trend in winter (late January-early February) correlated well with high contents of mercury, as well as lead, in the near-water air layer and in the atmospheric precipitations (Fig. 8).

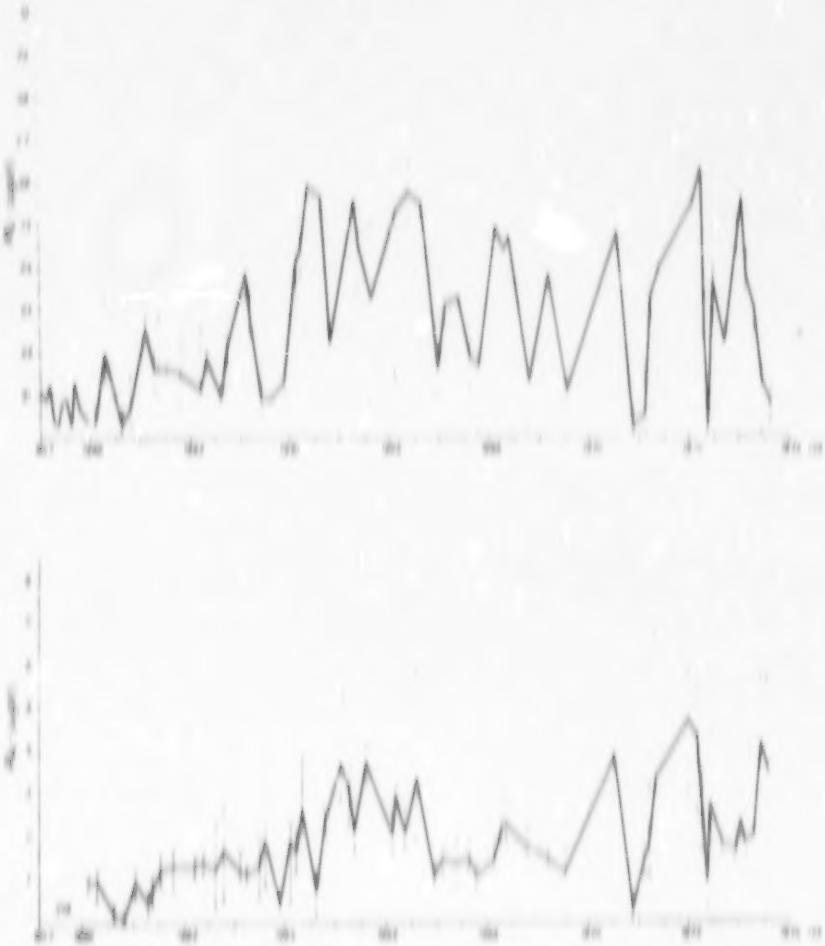

Figure 5. Phosphate concentration (mean and amplitudes) in the surface (0-20 m) and deep waters (80 m to bottom) of the Gdańsk Deep, 1960-1973, compared with the multiyear averages (Słowińska, 1963) for 1947-1960

A great span of sampling during one-week cruises together with high dynamics of water circulation were the assumed reasons for "spotted" distribution of total mercury in the surface layer of the Gdańsk Basin. We therefore introduced a synoptic approach, i.e., measurement of selected water constituents within the shortest possible time, which in our work was 24-30 hours.

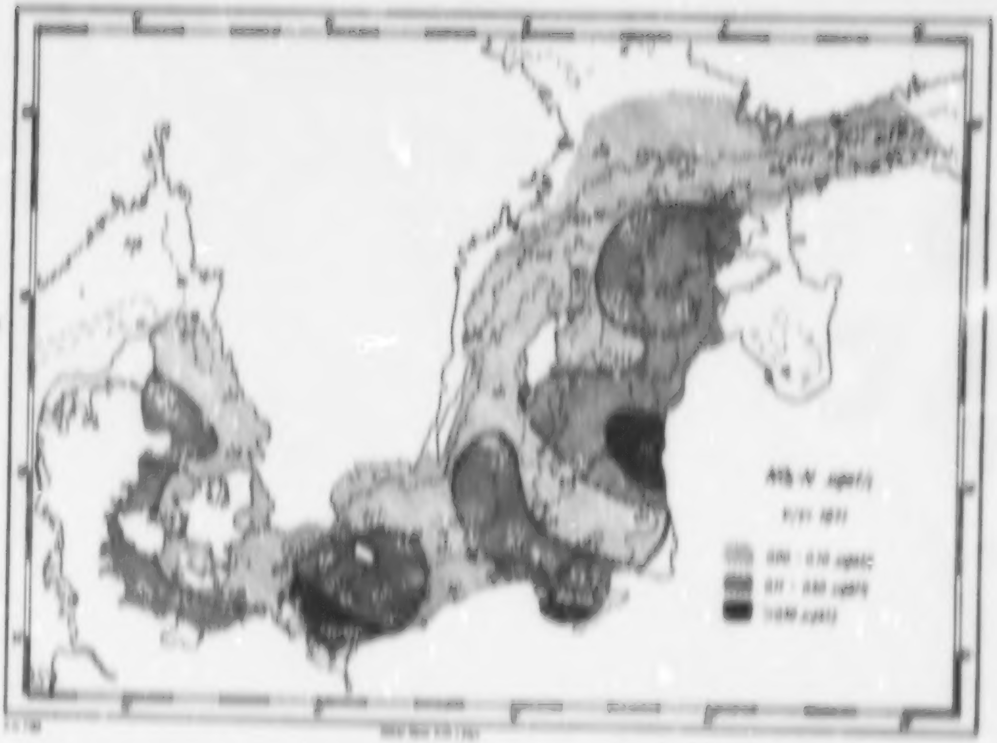

Figure 6. Approximate distribution of nitrates in the surface layer of the Baltic Sea.

However, data resulting from synoptic measurements (Fig. 9) confirmed a heterogeneous mercury distribution. They also demonstrated that the Vistula River cannot be considered as the only basic source of mercury for the region examined. Several months of measurements carried out daily and periodically in the mouth of the Vistula averaged 1,0 µg Hg/liter, with deviations of ±0,7 µg/liter (Fig. 10). The total mercury concentrations found simultaneously in the Gdańsk Basin were 20-30% higher.

The participation of organomercury compounds in the river water, ranging from 40 to 70%, were of the same order as in Baltic waters, where the organic fraction evidently prevailed, with a downward trend in summer. The vertical distribution of inorganic forms demonstrated more or less constant ratios, except for the sea/air and sea/bottom interfaces. Conversely, the concentration of organic forms underwent considerable variation with the upward trend in the pycnocline layer (Fig. 11).

The first attempt to evaluate yearly input of mercury into the Gulf of Gdańsk from anthropogenic sources resulted roughly in some 30 tons whereas the atmospheric component constituted about 30%. Accordingly, for the present conditions only 5-10% of the mercury accumulation in the Gulf of Gdańsk can be attributed to its natural origin.

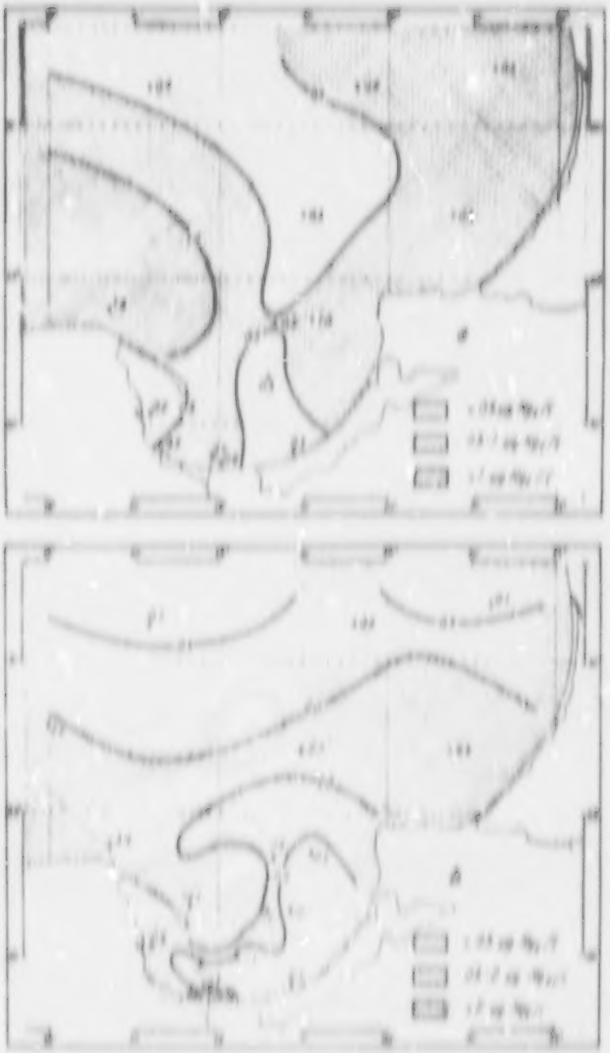

Figure 7. Approximate distribution of total mercury concentrations in the surface waters of the Gdańsk Basin, 1974, in (a) April and (b) December

In summary, the investigations covered by the current program emphasize the primary sources of marine pollution, with river discharges and the atmosphere, including water dynamics, being the decisive factor for the spreading of pollutants at sea. In this respect an attempt was made to obtain a provisional balance of selected pollutants. Such a schematic picture, irrespective of its useful character for marine environmental protection purposes, cannot be complete unless we take into account the processes that occur in the remaining interfaces, i.e., those of water to bottom sediments and suspensions as well as water to living organism contact zones. The problems, so far of marginal interest in view of the limited capacity of our laboratories, will be the object of more intrinsic researches in the near future.

It should be stressed here that there is yet another zone of separation within the Baltic Sea environment--the pycnocline. According to our prior experiences, this layer is essential for the distribution pattern of substances present in the Baltic water column and their further circulation. To tackle this question, however, special techniques are necessary, largely based on in-situ measurements which afford the possibility of precise and more frequent sampling from the narrow, strictly defined water layer. Conceptual studies to set up appropriate procedures are now in progress.

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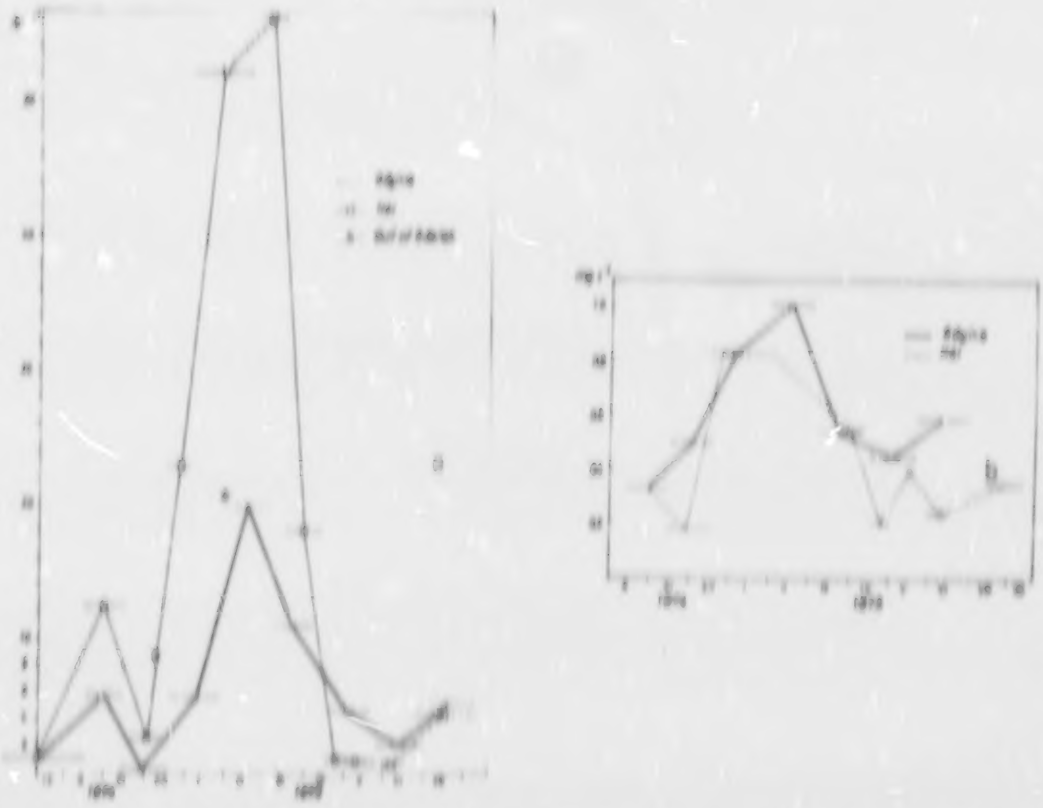

Figure 8. Time variations of total mercury (a) and lead (b) content in the atmospheric precipitations

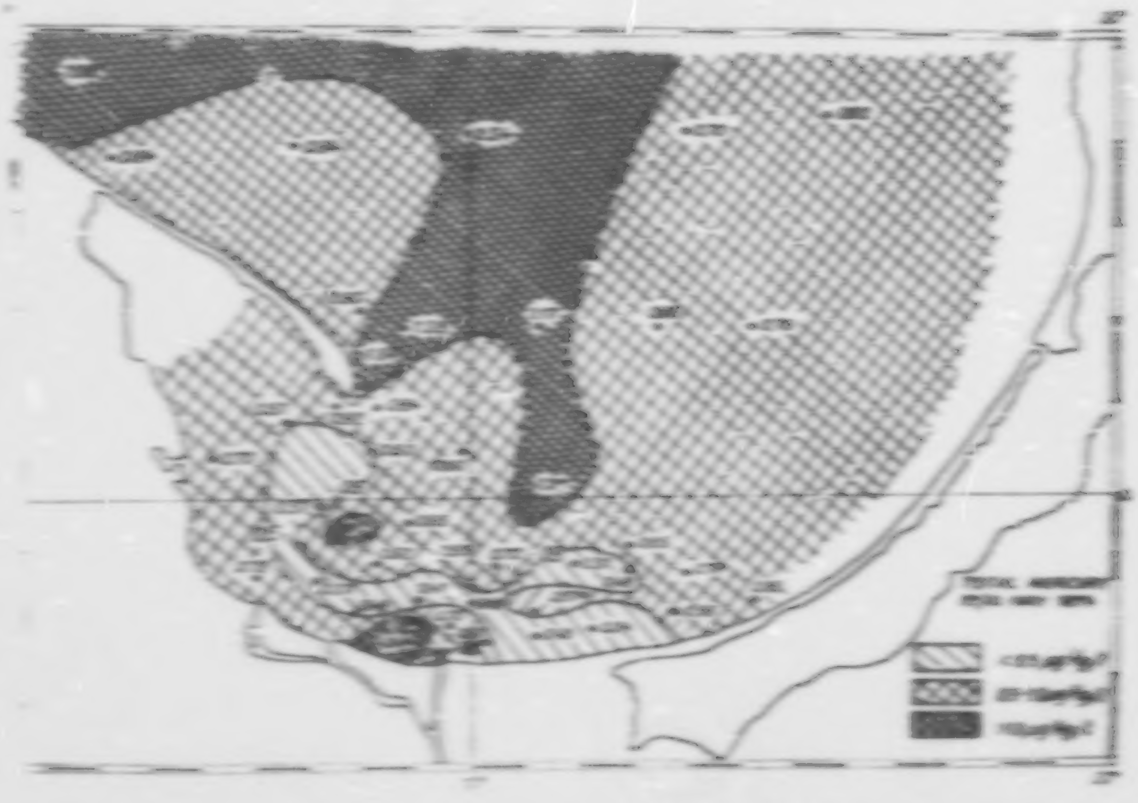

Figure 9. Synoptic picture of total mercury distribution in the surface waters of the Gdańsk Basin in May 1975

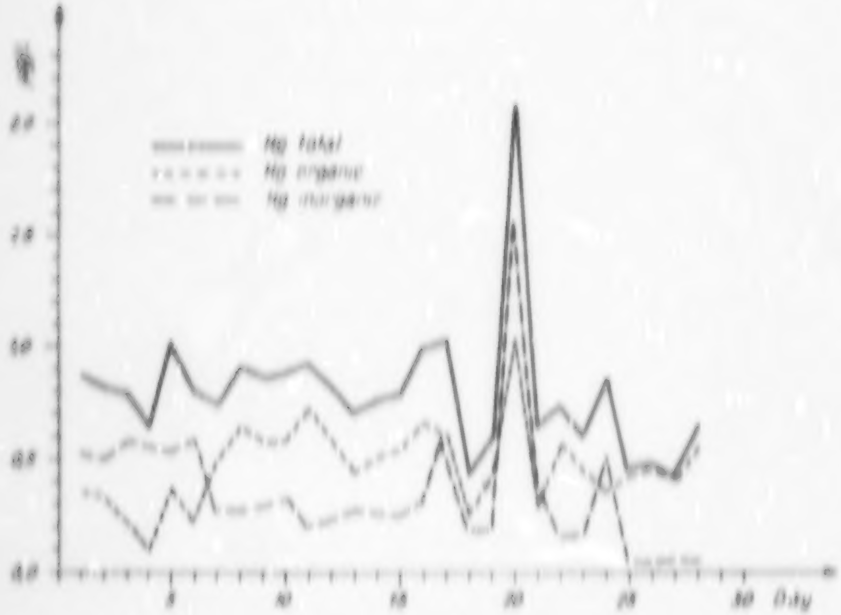

Figure 10. Mercury compounds concentrations in the mouth of the Vistula River; daily measurements for May 1975

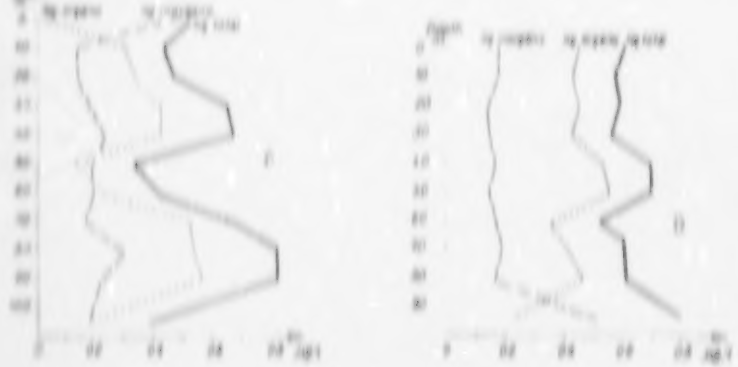

Figure 11. Vertical distribution of mercury in the central (a) and northern (b) parts of the Gdańsk Deep

INVESTIGATION OF POLLUTION-STRESSED LITTORAL COMMUNITIES IN THE NORTHERN ADRIATIC

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ABSTRACT

The distribution and general features of several littoral communities in the northern Adriatic have been surveyed over the past 3 years with special regard to oil and ore pollution. Field observations near Rovinj, the Island of Lošinj, and in Rijeka Bay were made along transects by divers. The fouling process and the sanitary aspect of shellfish rearing places were controlled also.

Communities of the supralittoral rocks are generally unaffected by polluted waters, rather, they are distributed in relation to physiographical features of the habitat. The community of the mediolittoral rocks is most stable in polluted regions, but it can become deteriorated due to continuous oil influences. The most resistant organism is the barnacle *Chthamalus stellatus*, which can survive under a layer of tar one centimeter thick.

In the area surveyed, the most pollution-affected benthic communities are the biocoenosis of photophilic seaweeds and the beds of marine phanerogams, which vanished recently from vast areas in the northern Adriatic. The photophilic seaweeds are usually limited to a narrow zone in the upper infralittoral, but frequently are replaced by dense populations of the common sea urchin *Paracentrotus lividus*.

Other communities were seldom affected by pollution in the investigated area, except in localities where intensive siltation takes place. In such areas, the transitive tendencies of sand and detritic bottom communities to those of coastal terrigenous ooze are noticeable.

Laboratory bioassays on the synergistic effects of lead and temperature/salinity on selected benthic species (seaweeds, shellfish, crustacea, and fish) were conducted.

DESCRIPTION OF RESEARCH

Long-term pollution in an aquatic environment can be best traced by large-scale change in benthic communities, even if the waste influx into the habitat is small. The dynamics in benthic communities is slower as a rule than in communities of open waters, especially in those benthic communities where pluriannual sessile species predominate. In these communities the changes in species composition of fauna and flora, and in quantitative relations between taxa, is slow but the effects of environmental factors causing changes remain perceptible for many years, especially if weak effects are summarized in the function of time.

Nowadays, because of progressive pollution of the seas world-wide, it is often difficult to say which littoral community might be still in its pristine condition; perhaps it is already affected by a factor which was not studied until the present. This is true in the north Adriatic, which is directly influenced by aerial pollution and by fresh water inflow of a great variety of pollutants (GFCM, 1972). It was presumed, however, that for the achievement of benthic communities in the pollution-stressed and relatively closed Gulf of Rijeka it is indispensable to investigate the benthos also in the area exposed to open sea, "washed" by permanent currents of clear water, and which is as little populated as possible. For this reason, the outer coasts of the islands Lošinj and Ilovik were chosen as the investigated area of the last "clear" localities in the Adriatic Sea. Additional field and laboratory observations were made also on the west coast of the Istrian peninsula, i.e., in the shellfish rearing places in Pomer Bay and in the Limski canal (Lim Fjord), as well as in the moderately polluted surroundings of Rovinj. All animals and plants which were used in various field and laboratory experiments were collected in these cities (Fig. 1).

Most resistant to the changes of environmental conditions are organisms living in extreme habitats, i.e., the marine supralittoral and mediolittoral zones. These zones are also the most exposed to undesirable effects of man's activities--to urban pollution caused by population concentrations, to heat and chemical pollution from industrial activities, to oil pollution involved in man's activities, ship disasters, and only rarely by natural sources. Furthermore, the organisms living in these zones are exposed to aerial pollution as well, at least at low-water periods.

Searching for a pollutant which can affect marine coastal life, and whose concentrations in the environment are increasing constantly, we decided to devote attention to lead (Pb). This metal is entering sea water world-wide, mostly by means of aerial pollution from gasoline motors, but also in smaller quantities through fresh water and industrial sewage inflows. The effects of lead on marine organisms were, however, seldom a subject of special investigation, and such observations were not conducted on species common in the littoral communities of the Adriatic Sea.

Finally, special emphasis was given to pollution influences on the sanitary condition of the Mediterranean mussel *Mytilus galloprovincialis*, a pilot species in communities of mediolittoral and infralittoral rocks, and which is also commercially reared in several shellfish beds.

RESEARCH OBJECTIVE AND APPROACH

Field research on distribution and ecological features of littoral benthic communities was conducted primarily in the Gulf of Rijeka and its branch (Bakar Bay), regions which are most affected by urban and industrial pollution in comparison with all other cities on the Yugoslav Adriatic coast. The Gulf of Rijeka (45°21'N, 14°26'E) lies in the triangle between the mainland massives of Risnjak and Učka Mountains, and the two greatest islands in the north Adriatic, Krk and Cres. The Gulf connects with other parts of the Adriatic Sea only through three narrow straits. The greatest depth is 65 m, with a muddy bottom. The shore is rocky, and consists of limestone. The Gulf is very rich in various karstic formations, such as underwater caves and underwater springs of fresh water ("vrulje"). The Gulf is exposed to waves from the south ("jugo") and to the strong northeastern wind ("bora").

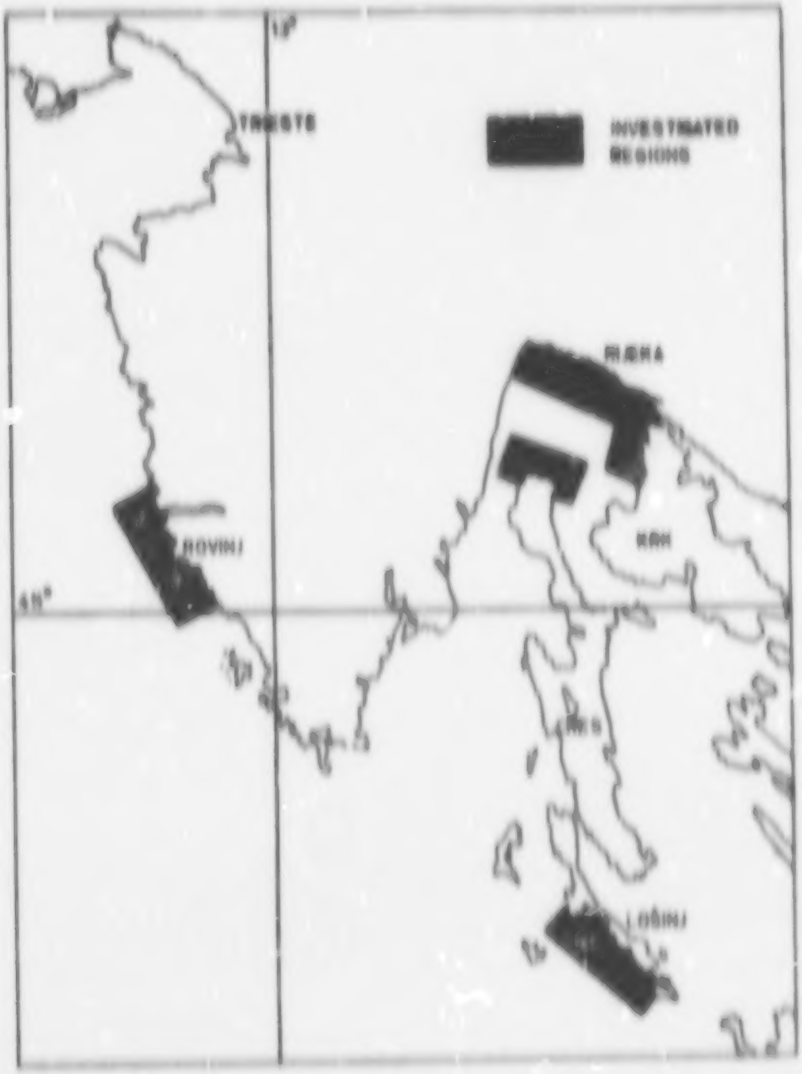

Figure 1. Investigation of pollution-stressed communities in the northern Adriatic Sea

The Gulf of Rijeka is strongly affected by the wastes of two direct sources: (a) domestic, especially urban, wastes resulting from greatest urban concentration on the eastern coast of the Adriatic (Rijeka with 120,000 inhabitants; the tourist resorts of Mošćenička Draga, Lovran, Opatija, Omišalj), Malinska and many others which are overcrowded during the main tourist season); and (b) industrial wastes discharged by paper mills, shipyards, chemical plants, two refineries, and others; industrial activities are concentrated in Rijeka and vicinity.

The comparative field research was made in a "clear" region of the island of Lošinj (44°23'-44°28'N, 14°28'-14°33'E), one of the large external islands in the north Adriatic. Its southwestern coast is fully exposed to winds and waves from the open sea. The localities investigated are sheltered from the cold northeastern wind. The shore is rocky, consists of limestone, and is covered by evergreen macchia and pine woods.

Along the southwestern coast, due to a permanent main current coming from the south, the bottom is sandy until the greatest depths (more than 60 m) begin in this part of the Adriatic Sea. The bottom along the opposite, mainland-oriented, coast is muddy. The water is very clear all around this sparsely populated island, except in the main bay where the harbor of the largest town, Mali Lošinj (4,500 pop.), is located.

Complementary field research was made in the region of Rovinj (45°05'N, 13°38'E), one of the largest tourist resorts in the northern Adriatic. The rocky shore is usually slightly sloping to depths of 30-32 m, with a sandy, detritic, or oozy bottom. The shore is relatively sheltered from the "bora," but is fully exposed to winds and waves from the open sea. The main north-directed current flows within 5 miles of the coast. Despite numerous hotels and campsites, the sea is generally clear, but effluents from the "Mirna" fish cannery often pollute coastal waters in the entire area. Oil and tar deposits are scarce on shore.

The shellfish used in field and laboratory experiments were provided from rearing places in Pomer Bay, the harbor of Pula, and Limski canal. The shellfish were reared on stable wood constructions, at depths of 1-3 m. The sea is heavily polluted only in Pula harbor. For this reason, this rearing place provides only the spat.

At investigation sites, biocoenological observations of benthic communities were performed along the transects about 1-2 km apart. Each transect was marked with a nylon rope, which ran from the supralittoral zone to depths of 20-45 m, or in shallower localities, 200-300 m from the shoreline. The observations were made in situ by scuba divers using underwater photography for documentation purposes. Only macroflora and macrofauna were considered. Samples were taken by divers, using a 1-m² frame, at random or at places indicated by biologists. In the supralittoral and the mediolittoral zones the communities were thoroughly analyzed by means of a wire frame 25 x 25 cm. Plants and animals were counted and covering rate was estimated for each species. If the populations were scattered, more squares in each zone and transect were analyzed, but the results were later plotted as average values. The analyses were done according to the method of Braun-Blanquet (1921). The terminology of the French school (Pérès and Picard, 1964; Pérès, 1967) was applied.

The settings of sessile organisms in Bakar Bay and near Rovinj were monitored on inert glass test panels, exposed at the surface and at 150 cm depth. Hydrographical and bacteriological analyses were made according to standard methods used in other routine investigations of the Center for Marine Research.

The toxic effects of lead on selected benthic species were studied in solutions of $Pb(NO_3)$ in normal and diluted sea water, under controlled temperature conditions. Medium concentrations of lead nitrate were prepared by calculations (100-1000 ppb) and were controlled by subsequent determinations by anodic stripping technique with rotating glass carbon electrode (RGCE) (Florence, 1970). The concentrations used in this experiment were not the same for all species studied, however, they were chosen with regard to age, dimensions and resistance ranges of specimens. All experiments were conducted in glass beakers.

ACCOMPLISHMENTS TO DATE

In the northern Adriatic, the supralittoral limestone rocks are occupied by a single community characterised by the following pilot species: endolithic *Cyanophyta*, epilithic *Chthamalus depressus*, *Littorina neritoides*, and often the lichen *Verrucaria adriatica* as well. Most frequent in the lower horizon, however, is the barnacle *Chthamalus stellatus* of which the most dense populations are located in the upper mediolittoral zone. Near Rovinj and in the Gulf of Rijeka, in the fissures amid the supralittoral rocks, the enclaves of seaweeds *Rivularia atra*, *Catenella opuntia* and *Lithophyllum tortuosum* (which are typical mediolittoral species) were also observed. In the investigated area, the community of supralittoral rocks can establish more than 4 m above the tide mark, which depends on the exposure of the locality. Our observations indicated that this community is generally not affected by polluted water, except in the petrol harbor where it is deteriorated due to the overlay of oil.

Because of weak tides, the community of the mediolittoral rocks is limited in the northern Adriatic only to the zone about 30-50 cm high. Characteristic species of this community are: *Chthamalus stellatus*, *Patella lusitanica*, *P. coerulea*, *Gibbula adriatica*, *Actinia equina*, *Lithothamnion lenormandi*, *Lithophyllum tortuosum*, and *Fucus virsoides*. *Mytilus galloprovincialis*, *Ulva lactuca* and *Cladophora* spp. are differential species which usually indicated increased amounts of nutrients in the sea water. However, mussels can also indicate a drop in salinity values below normal, due to steady surface or underwater inflow of fresh water.

The most remarkable populations on mediolittoral rocks are those of the barnacle *Chthamalus stellatus*. As many as 10-11,000 specimens/m^2 can be enumerated, covering more than 70-80% of the rock surface. These barnacles are very resistant to pollution and can be found almost everywhere. Sometimes they were found alive even below the 1-cm thick layer of tar; the animals were in contact with the surrounding sea water only by means of a narrow hole pierced through the tar. The mortality of these barnacle populations was surprisingly low and did not exceed 10%. The overlying surface oil cover, however, is also hazardous to barnacles. Thus, in the immediate vicinity of petrol harbor and the effluent discharges of the refinery, no living macroorganism was found in the mediolittoral zone. A similar "abiotic" belt also stretches in Valdibora Bay near Rovinj, where fat deposits from effluents of the "Mirna" fish cannery are about 2 cm thick. At other moderately polluted sites mussels and barnacles at least survive.

Higher algae, except nitrophile species, are generally sensitive to polluted water. Therefore it is very interesting that the endemic brown seaweed *Fucus virsoides* tolerates environmental conditions in those localities moderately affected by mineral oils and organic fat residues, and does not deteriorate even if thalli are partially covered by tar deposits. Furthermore, surface oil film did not prevent the setting of diatoms and green algae on our test panels at sea level in the harbor of "INA" oil refinery.

On hard bottoms, the upper infralittoral zone is occupied by a community of photophilic seaweeds. This is one of the most important benthic communities in the Mediterranean, in view of its covering rate, standing crop, productivity, etc. However, this community at the same time is the most sensitive to environmental pollution. Leading (pilot) species of this northern Adriatic community are various representatives of the genus *Cystoseira* (primarily *C. barbata*, *C. abrotanifolia*), *Dictyota*, *Padina pavonia*, *Halimeda tuna*, *Sargassum*, etc. The degradation phase involving natural forces (exposure, water dynamics) usually is marked by the preferential appearance of *Padina pavonia*, *Laurencia obtusa*, and encrusting red algae; the nitrophile environment is characterized mostly by settlements of *Codium* (*C. bursa*, *C. tomentosum*), *Cladophora*, *Ulva*, *Dictyopteris polypodioides*, and *Halopteris scoparia*.

In the northern Adriatic, at sheltered pollution-free localities, the standing crop of dense settlements of photophilous seaweeds is often 5-10 kg fresh weight/m^2 (Munda, 1973; Zavodnik, 1972). The algal belt can reach depths of 10-15 m. In deeper waters, photophilous algae are replaced by the praecoralligenous facies on hard and/or detritic bottoms, while on sandy bottoms (pure or partly mixed with ooze) they are followed by meadows of marine phanerogams. Conversely, in the investigated area, at moderately polluted sites, the algal belt is limited usually to only 2-3 m depth, and in heavily polluted localities the community completely disappears or only a low turf of filamentous algae--*Padina*, *Laurencia*, and melobesias--remains. Simultaneously, the algal standing crop and primary productivity in this zone decrease drastically, probably affecting other ecosystems.

At increased pollution levels, leading species of *Cystoseiretum* disappear first, above all the most luxuriantly growing and ecologically important *Cystoseira barbata* (Golubić, 1968; Bellan-Santini, 1969). This species is used as an indicator of clear waters throughout the Mediterranean, but recently an excellently developed settlement of *C. barbata* was recovered in the polluted harbor of Koper in the Gulf of Trieste. Consequently, further autecological studies of this species are needed. It should be added that the only ubiquitous algal species in the investigated area seems to be *Dasycladus clavaeformis*, of which dense settlements are common at moderately polluted and clear sites, and on all kinds of bottom materials.

At several localities, the rocky and gravel bottom was completely denuded, and forests of seaweed were replaced by populations of the common sea urchin *Paracentrotus lividus*. Several hypotheses on the interdependence of sea urchins and seaweeds exist, but none is yet proved. In the vicinity of Rovinj, at visually clean sites, vast zones of rocky bottom were completely derived of *Cystoseiretum* within the past five years, which is reflected in a reduction in algal biomass from 5,000 g to only about 20 g/m^2. Furthermore, the denuded surfaces were often less occupied by sea urchins or not at all.

General and universal deterioration of photophilous seaweed communities in the northern Adriatic can be stimulated by an environmental factor not yet identified, or by simultaneous interactions of several factors, probably caused by pollution. It is proved, however, that universal specific changes in the phanerogam communities, and deterioration of several beds of phanerogams is directly caused by pollution (Pérès, 1974). This phenomenon was observed also in the area investigated by us, where

Posidonia oceanica and *Zostera* beds are replaced by *Cymodocea nodosa* (western coast of Istria, Gulf of Rijeka) or phanerogams disappeared completely (Bakar Bay).

In the area studied several other benthic communities were discovered in the infralittoral zone, but these do not seem to be directly affected by oil or sewage pollution, except in the harbors. In this context, the important effect of silting must be emphasized. This phenomenon is especially evident in Bakar Bay, where due to unloading of ore cargo, enormous quantities of inorganic detritus particles are dispersed in the aquatorium. The rocky and sandy bottoms are covered overall with a thin layer of silt and the advanced transformations of pure coastal detritic bottom community to that of detritic bottom mixed with ooze, and to the community of coastal terrigenous ooze, were observed.

The siltation did not prevent settling of shellfish, tube-worm and bryozoan larvae on test panels. However, on the hard bottom, which is steadily affected by iron-ore siltation, populations of macro-benthic animal species are sparse, consisting mainly of endolithic shellfish (*Gastrochaena dubia*), clionid sponges, and serpulide tube-worms. The population density of serpulids (chiefly *Pomatoceros triqueter*) can exceed 3,000 specimens/m^2.

It is assumed that bacterial pollution is generally not harmful to benthic organisms and/or communities, but it must be considered if organisms are to be used for commercial purposes. Our results indicate that the accumulation factor in the reared mussel *Mytilus galloprovincialis*, with regard to the environmental sea water in rearing places, is a minimal 300 for total coliforms, 30 for fecal coliforms, and 450 for fecal streptococci. In the sanitary clear water, bacterial numbers of mussels contaminated in the Rovinj harbor decreased within four days about 10^3-10^4; subsequently, the purification process was much slower.

Extensive studies were conducted also on the synergistic effects of lead with several environmental factors on the following selected benthic organisms: the seaweeds *Ulva lactuca*, *Padina pavonia*, *Fucus virsoides* and *Laurencia obtusa*, the mussel *Mytilus galloprovincialis*, the shrimp *Palaemon elegans*, the crab *Carcinus mediterraneus*, and the fishes *Blennius pavo* and *Diplodus annularis*.

It was found that lead concentrations in the range tested (100-1000 ppb) are below levels detectably toxic to seaweeds in short-term tests. These concentrations had no appreciable effect on oxygen production in algae studied. In identical illumination conditions, photosynthesis depends more on temperature and salinity conditions than on lead nitrate content of the medium.

Lead affects oxygen consumption and behavior of adult test animals, with special regard to their locomotion, molting in crab, and aggregation in mussel (Teskeredžić, 1974). In no single species could the lethal or LD_{50} dose be established for adults. But in fish, the basophile punctations of red blood cells are an indication of lead poisoning (Teskeredžić, 1975). These punctations appear when the lead concentration reaches 10 μg/g dry substance.

When exposed to contaminated sea water with 500 and 1000 ppb in a one-month period, lead uptake was the highest in the meat of mussels (about 2000 μg Pb/g dry weight), and much less in crabs (about 320 μg Pb/g) and in peacock blennies (50 μg Pb/g). It seems that lead uptake in animals depends upon the manner of food consumption: the mussels (filter-feeders) concentrate much more lead in their bodies than do the peacock blennies (carnivores) which do not ingest the contaminated food. In mussels, the release of lead was very slow.

In mussel larvae, the deleterious effect of lead results in abnormalities of shell development, and in inhibited development of straight hinge larvae, especially at high temperatures and low salinities. Salinity and temperature ranges for optimal embryonic development diminish in the presence of lead ions in sea water, and the mortality of larvae increased with increased lead nitrate content of the medium. It seems that recruitment of mussels in littoral communities is not seriously affected at lead concentrations below 100 ppb.

FUTURE PLANS

While the relevant EPA project (No. 2-512-3) research is terminated, this does not mean the research topics are completed. To the contrary, a number of unexpected fundamental problems have appeared, and new ideas evolved contemporary with future industrial and urban progress in the area. Erecting of new petrochemical complexes, the new petrol terminal and the thermo-power plant in the very near future in the Gulf of Rijeka suggest the need for a long-term monitoring program in the entire northern Adriatic. On the other hand, basic problems of universal phenomena, such as pollution effects on benthic and pelagic communities and selected species, productivity, biodeterioration and biodegradation, and similar parameters require interdisciplinary and international cooperation in simultaneous, identical research at representative sites world-wide. I propose that such overall investigations of benthic communities be initiated and coordinated by EPA. The Center for Marine Research in Rovinj is willing to cooperate fully in such research.

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MICROBIOLOGY AND CHEMISTRY OF ESTUARINE SURFACE MICROLAYERS

A. W. Bourquin[1] and D. G. Ahearn[2]

Organic microlayers occur at the air-water interface of most bodies of water. The microlayer or "sea slick" formation appears to be related mainly to decay of naturally occurring aquatic organisms or to their production of lipodial by-products (Babkov, 1965). Sea slicks are known to influence wave action and height, air-water temperature exchange, stability of bubbles and foams, and the concentration of salt-containing micro-droplets in the marine atmosphere (Baier, 1970). In coastal regions particularly, the direct activities of man are of increasing importance in the generation of surface slicks. Industrial and municipal sewage effluents constitute the major source of films and foams, but crude oil spillage appears to be a major contributor in localized areas (Ahearn, 1974).

Baier (1970) suggested that the compaction of surface films by wind and waves generates much of the detrital food for plankton in the water column. A few studies indicate that microbial activities within the surface slick itself are of significance in detrital formation. Sieburth (1965) reported bacterial populations up to 4 x 10^4 ml^{-1} in surface films. The predominant bacteria were pseudomonads which expressed lipolytic activity. Harvey (1966) found that bacteria, small algae, and colorless flagellates were concentrated in the upper 60 µm of surface water. Numerous investigators (Baier, 1970, 1972; Ewing, 1950; Garret, 1965; Sutcliffe et al., 1963) have examined the physical properties of surface slicks, but their chemical nature is unclear and apparently highly variable. Surface microlayers have been shown to contain high concentrations of organic carbon, nitrogen and phosphorus (Williams, 1967), alkanes and chlorinated hydrocarbons (Seba and Corcoran, 1969; Ledet and Laseter, 1974) and organometal complexes (Church, 1975). Concentrations reported for various pollutants are given in Table 1. Grimes and Morrison (1975) showed that the bacterial bioconcentration of chlorinated hydrocarbon insecticides from aqueous systems is a commonly occurring phenomenon. Such binding of pesticides to cells suggests that the presence of chlorinated hydrocarbons in surface films (Seba and Corcoran, 1969) may be related in part to their microbial densities.

In studies from our laboratories on a yeast isolated from a fresh-water oil layer, the chlorinated pesticide heptachlor either stimulated or inhibited hexadecane utilization dependent upon cultural conditions (Smith et al., 1976). The heptachlor was bound to the yeast cells but no direct evidence for its metabolism was obtained. Stimulation of oxidation of hexadecane in the presence of a non-utilizable substrate by a fungus (*Cladosporium resinae*) has been shown also by Walker and Cooney (1973).

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Growth inhibition of estuarine microorganisms by polychlorinated biphenyl formulations has been demonstrated in laboratory studies (Bourquin and Cassidy, 1975; Bourquin et al., 1975) and field and laboratory studies have shown that crude oil may diversely affect the various species of the estuarine microecosystem (Ahearn et al., 1971; Crow et al., 1975b; Hood et al., 1975). The potential for alteration of the estuarine surface film microflora by hydrocarbons can be expected to increase with the advent of superports and the extension of offshore oil fields. For a better understanding of the composite phenomena affected by surface films, and their role in pollutant concentration or metabolism, a substantial increase in our knowledge of the chemical identity of surface films and of the changes in the film with microbial activity needs to be developed.

Table 1. Surface films--concentration factors

Location	Constituent	Concentration Microlayer	 Subsurface	Reference
		ng/ℓ	ng/ℓ	
Sargasso Sea	DDT	0.3-2.1	0.15-0.50	
	PCB	7.8-43.5	0.9-2.1	Bidleman, 1974
Biscayne Bay	DDT, DDE	0.7-12.7		Seba and Corcoran, 1969
		μg/ℓ	μg/ℓ	
Narragansett Bay	PCB	4.2±1	0.13±0.04	Duce et al, 1973
	Copper	7.2±2.3	0.2±0.09	
	Fatty Acids	120±26	36±7	
	Hydrocarbons	8.5±1.7	5.9±1.2	
North Mediterranean	Phosphate, Nitrate	2-5x	1x	Dumas, 1974
Unknown	Copper	100x	1x	Church, 1975

ACCOMPLISHMENTS

Surface slick samples were collected by a membrane adsorption technique (Crow et al., 1975a). Sterile Nuclepore® membranes (47 mm diam, 0.4 μm pore size, Nuclepore Corp.) were floated on the water surface. The thickness of the microlayer sampled varied depending upon physical conditions and the chemical nature of the film. Heavy hydrocarbon slicks can be expected to be sampled at thicknesses up to 50 μm and surface microlayers with no visible slick approximately 10 μm thick (Cook and Crow, unpublished data). The membranes, with adhering surface film, were retrieved by submerging sterile plastic plates under them and gently removing the filter and underlying water; the membrane was then removed from the plate with forceps. In calm water with little wind we often retrieved filters directly with forceps. Other membranes (cellulose, cellulose acetate ester) tested for adsorption sampling were not suitable because they either sank when completely wetted or adsorbed more water than desired for microlayer sampling. For microbiological analyses, the membranes were placed in bottles containing 100 ml of sterile seawater and transported to the laboratory, usually within 30 minutes. The bottles were agitated vigorously on a wrist-action shaker for 3 minutes, and the water was diluted serially. One-tenth milliliter of the required dilution was inoculated onto the appropriate medium. For enumeration of fungi, membranes often could be placed directly on nutrient medium.

Subsurface samples (10 cm depth) also were taken at each site with sterile 30 ml disposable syringes fitted with sterile extension tubes. These samples were expelled into sterile containers for microbiological analysis.

Marine agar 2216 (Difco) was used for bacteria, and mycological agar (Difco) prepared with seawater and adjusted to pH 4.5 for fungi. All media were incubated at 20-25 C until colonies became visible.

Microbiological analyses of surface microlayer from our laboratories (Crow et al., 1975a, 1976) show that inshore films yield microbial populations up to 10^8/ml^{-1} or 10^5/cm^{-2}. These populations were typically 10 to 100 times greater than those in underlying waters at a depth of 10 cm. Predominant bacteria in the films were motile, non-pigmented, gram-negative rods. Colony-forming units of yeasts and molds were found in concentrations of 10^4/ml^{-1} or 28/cm^{-2}. The predominant species in the surface films were proteolytic and amylolytic but exhibited only weak to negligible hydrocarbonoclastic and lipolytic activities. A greater proportion of the surface film bacteria, as compared with those at 10 cm depth were capable of growth on media prepared with fresh water.

Table 2. Concentration of microorganisms in surface slicks and underlying water

Organisms	Surface slick		Subsurface	Number of Samples
	(ml^{-1})	(cm^{-2})	(ml^{-1}) (10 cm depth)	
Bacteria	10^3-10^8	28-2.5 x 10^5	10^2-10^6	24
Yeasts	10^2-10^4	0-5	10^2	16
Molds	10^3-10^4	0-28	10^2	16

Adapted from Proceedings of Third International Biodegradation Symposium, Rhode Island, 1975.

Table 3. Characteristics of microorganisms from an estuarine surface slick

Bacteria	Colony-forming units/cm^2	
	Number	Percentage of total
Proteolytic	2.0 x 10^3	0.80
Hydrocarbonoclastic	3.0 x 10^2	0.12
Growth in fresh water	-	61.9
Total heterotrophic population	2.5 x 10^5	100.0

Samples for chemical analyses required larger volumes than those retrieved for microbiological sampling. Multiple Nuclepore® membranes (293 mm diam, 0.4 µm pore size) were floated on visible slicks, retrieved with clean forceps, and placed in pre-rinsed glass bottles (with teflon-lined caps) containing 500 ml petroleum ether (nanograde, Mallinckrodt, St. Louis, Mo.) to inhibit microbial growth which may cause further degradation of the chemical constituents of the slick. With obvious heavy surface slicks this technique provided qualitative sampling for gas chromatographic-mass spectral analyses (GC-MS). The procedure has not yet been adapted to quantitative sampling.

Samples have been extracted for chemical analyses using two different methods. Membranes were extracted with petroleum ether; the petroleum ether fraction was concentrated to 5 ml and added to a 30-cm activated silica gel column. The column was eluted with 50 ml petroleum ether followed by 25 ml acetone. Elution solvents were collected in 5-ml fractions for gas chromatographic analyses. Each fraction was analysed using flame-ionisation and electron capture gas-chromatographic techniques.

Alternatively, samples can be washed from the membranes with water and extracted with 75 ml 15% (v/v) methylene chloride in petroleum ether to obtain a more polar extraction. The portions are combined and evaporated to approximately 0.5 ml. The aqueous fraction is then re-extracted at pH 4 and again at pH 11 with 300 ml 15% (v/v) methylene chloride in petroleum ether. The three extracts are then concentrated to 0.5 ml each and analysed by gas-chromatography and mass spectroscopy.

Gas chromatographic (GC) analyses indicate the films consist mainly of a broad mixture of aliphatic hydrocarbons which boil at temperatures greater than 120 C. Although no confirmed identifications can be made by GC data alone, observation of the chromatograms (Fig. 1) indicates hydrocarbon constituents with a range of about C_{16}-C_{34} aliphatics. The double peaks shown in the chromatograms are typical elution patterns for alkanes-alkenes of the same carbon chain length. Mass spectral observations indicate aliphatic hydrocarbon splitting tendencies, i.e., loss of $-CH_2$ fragments (molecular weight 14). Complexities of the mass spectrogram (Fig. 2) indicate various branchings off the primary carbon skeleton of some of the aliphatic hydrocarbons. There are also indications of early eluting aromatic compounds with a tentative identification of an aromatic ether.

Concentrated surface slick samples were separated on a silica gel column, and various fractions indicated the presence of electrophilic compounds coupled with the higher abundance of hydrocarbons. Figure 3 shows the complexity of these samples. With confirmed identification of these compounds, we hope to obtain some information on the possible fate of chlorinated hydrocarbons in surface films. It is quite possible that at least some of the electrophilic compounds shown here are degradation products of organochlorine pollutants.

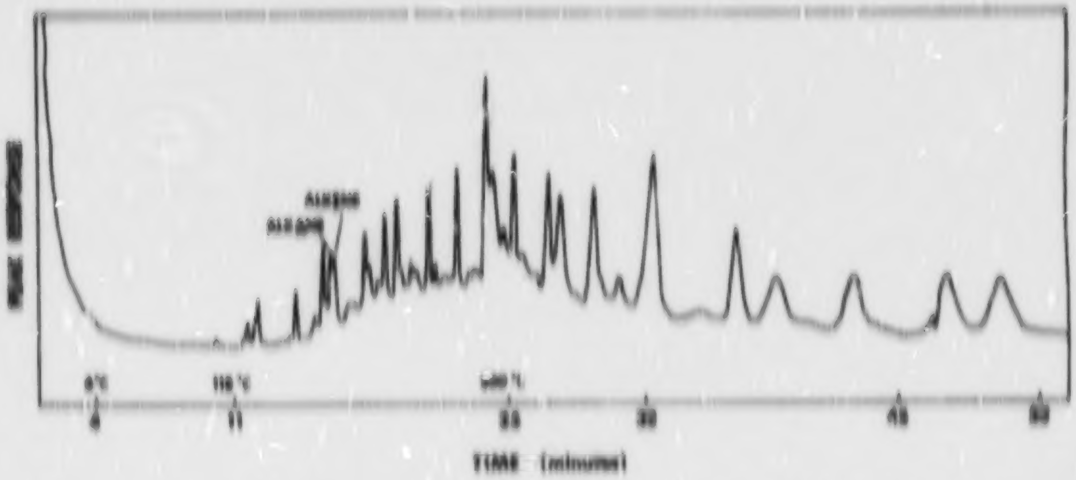
CRUDE SURFACE SLICK CONCENTRATE (FID RESPONSE)

Figure 1. Gas chromatogram from a petroleum ether extract of a Nuclepore sampled surface film. A varian-Aerograph 2100 was used with an OV-101 (2%) column using a flame-ionization detector and the following temperature program: initial temperature 75 C, 6 C/min for 30 min, hold final temperature of 255 C for 20 minutes.

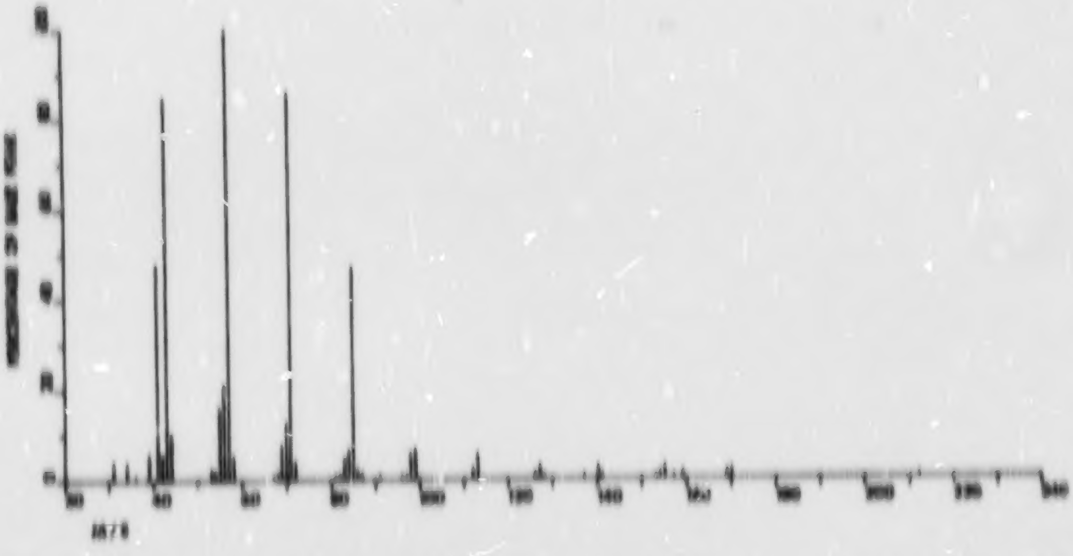
SPECTRUM NUMBER 53-51
SURFACE SLICK, BEAKER COLLECT, NEUTRAL pH

Figure 2. Mass spectrogram from surface film extract at a neutral pH. The sample was run on a Funnigan-GC-MS system. The spectrogram indicates typical breaking patterns for aliphatic hydrocarbons with some indication of branching.

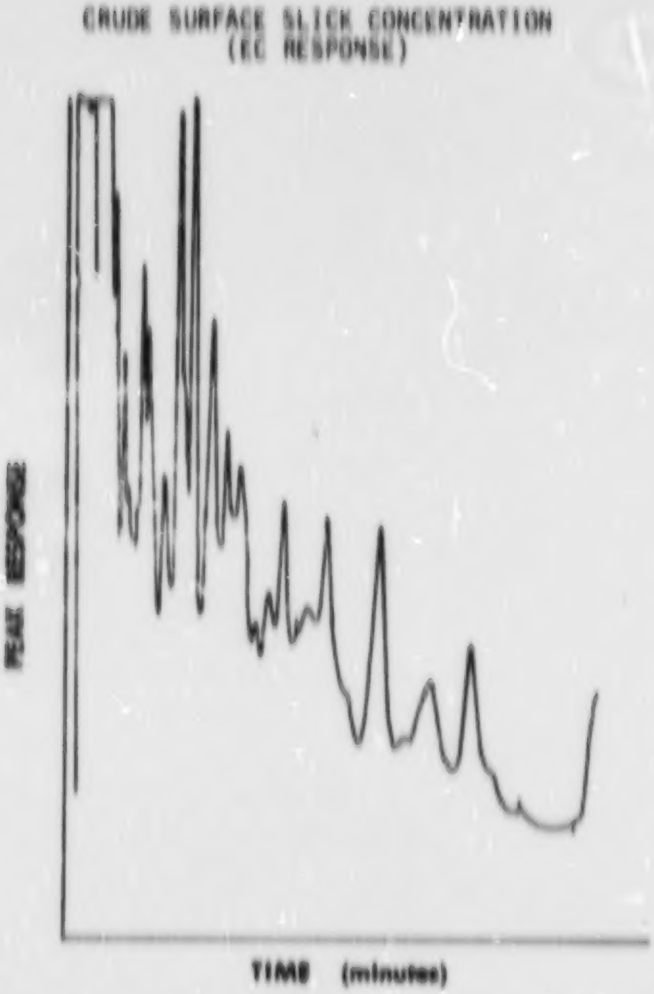

Figure 3. Gas chromatographic response from a petroleum ether extraction of a Nuclepore sampled surface film. Extracts were analysed on a Hewlett-Packard 5830A instrument with a 3% OV-101 equipped with an electron-capture detector and the following conditions: column 190 C, injector 200 C, detector 220 C, and carrier gas flow 60 ml/min.

FUTURE PLANS

Dense surface films contain large quantities of organic compounds, fatty acids, aliphatic and aromatic hydrocarbons of natural origin as well as constituents directly attributed to man's activities, that is, petroleum oil, hydrocarbons, and pesticides or PCB's. Recently, Hood et al. (1975) demonstrated the reliability of using ratios of specific microbial physiological activities as indicators of petroleum hydrocarbon intrusion in estuarine and coastal marine areas. We hope to extend these studies after clarification of the chemical constituents of various surface films to information on levels and types of microbiological activities associated with these films. In this way, we may be able to obtain a relatively inexpensive indicator of surface water quality.

In addition, microbial activity can lead to changes in the nature of various surface films, particularly with regard to pollutant constituents. We are currently investigating the role of surface film microorganisms in metabolism or co-metabolism of normally recalcitrant type molecules such as pesticides and heavy aromatic hydrocarbons. As shown in Figure 3, various electrophilic constituents exist in surface films which have not been confirmed as parent pesticides or PCB-type compounds. Laboratory studies on the metabolism of organochlorine pesticides by hydrocarbon-degrading microorganisms may help us determine the fate of these and other pollutants when they are concentrated in organically rich and microbiologically active estuarine surface microlayers.

ACKNOWLEDGMENTS

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SURVIVAL OF VIRUSES IN THE MARINE ENVIRONMENT

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INTRODUCTION

The discharge of large quantities of domestic wastewater into coastal waters is practiced throughout the world. Treatment of these discharges ranges from no treatment to tertiary treatment involving chemical flocculation.

Many viruses occurring in wastewaters are of human origin. Since large quantities of viruses are excreted with feces it is to be expected that many enteric viruses are present in wastewaters. Animal, plant, bacterial viruses and others are also found in various densities in wastewaters. Because viruses are very specific in their host range it is believed that non-human viruses are incapable of producing human disease. However, several examples have been reported whereby viruses naturally infecting one host may cause cancers in secondary hosts (Huebner et al., 1962; Girardi et al., 1962). Therefore, the occurrence of non-human viruses in sewage cannot be ignored.

It is known that many viruses survive waste treatment and chlorination of effluents (Berg, 1966; Kelly and Sanderson, 1958). Present in treatment plant effluents are many viruses whose fate in receiving waters is largely unknown. Because our epidemiologic understanding of the extent of transmission of viral disease by marine waters is limited, additional emphasis must be placed on the acquisition of basic knowledge on the fate of viruses in the marine environment. There is evidence that viruses discharged into receiving waters may easily adsorb to naturally-occurring silts and clays (Hamblet et al., 1969; Carlson et al., 1968). There is little information on the effect of this phenomenon on the survival of viruses.

Finally, the experimental data obtained from the Marco Island, Florida, sewage treatment plant, which consistently demonstrated an efficiency in excess of 90%, must be emphasized. The effective destruction of not only bacteria but also viruses by chlorine is dependent upon the absence of organic and inorganic particulate matter in the final effluent. Although pathogenic organisms and coliphage were consistently isolated from the raw influent to the Marco plant, on no occasion was a pathogenic organism or coliphage isolated from the final chlorinated effluent in 48 separate experimental attempts utilizing enrichment-selective culture techniques. These data support those of Clarke and Chang (1975; Clarke et al., 1962) that an efficient secondary sewage treatment with disinfection is required to ensure a final virus-free effluent.

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METHODS

Escherichia coli B bacteriophage T2 was used as the model virus to study the effect of particulates on virus survival. Samples of unchlorinated effluent and other sewage fractions were collected at the Virginia Key Sewage Treatment Plant, Miami, Fla. These samples were assayed on the same day to minimize loss of virus. All virus assays were done by a modification of the agar overlay method described by Adams (1959). Sewage samples were assayed for viruses producing plaques on *E. coli* B.

Chlorination experiments were carried out on samples of unchlorinated effluent on the same day of collection. The pH of these samples was usually 7.2; the experiments were performed at room temperature of approximately 25 C. The source of chlorine was household-type 5.25% sodium hypochlorite solution. Total chlorine was measured by the ortho-tolidine method. Chlorine was neutralized at predetermined contact times with 0.1 M sodium thiosulfate, virus plaque-forming units (PFU) were assayed, and coliform bacteria were enumerated by dilutions onto MacConkey agar. All samples for virus or coliform bacteria were assayed in triplicate.

Artificial seawater was prepared by using the values of Dittmar (Matossian and Garabedian, 1967). Natural seawater was collected in the Gulf Stream several miles east of Miami, Fla., and was used within 48 hr. Salinity and pH of all samples was 35 ppt and 8.1, respectively. Samples were stored at 4 C until used.

Loss of viral titer (LOT) was determined by dosing 100-ml aliquots of the various solutions with one ml of virus suspended in artificial seawater. These were incubated in 250-ml screw-capped Erlenmeyer flasks at 24 C in a rotary shaker set at 120 rpm. Viral infectivity was assayed initially and after a predetermined period of time. Loss of viral titer is indicated since a reduction in titer may be due to factors other than actual inactivation, for example, aggregation.

Kaolinite 4 clay (Ward's Natural Science Establishment, Inc., Rochester, New York) was pulverized in a mortar and suspended in double distilled water. After overnight sedimentation of the heavier particles, the clay suspension was centrifuged for 30 min at 3,020 G. The pellet was resuspended in distilled water and the suspension diluted to approximately 2,000 mg/liter for a stock solution.

In order to measure virus adsorption, clay suspensions were prepared by diluting the stock solution in 2X artificial seawater (70 ppt) in various proportions to obtain the desired salinity and clay concentrations. The pH was adjusted to 8.1 and double distilled water added if necessary to make up 100 ml total volume; 1 x 10^9 PFU in one ml artificial seawater was added and the flasks mixed for 30 min. According to Carlson et al. (1968), maximum adsorption to clays occurred within this time. Twenty milliliters were then removed and centrifuged for 30 min at 3,200 G, and the supernatant was assayed for virus. Viral removal was determined by comparing these results with the virus titer in a control sample without kaolinite.

RESULTS

Figure 1 shows inactivation of coliform bacteria and coliphages by total residual chlorine in sewage effluent (suspended solids 50 mg/liter). It is apparent that coliform bacteria disappear after 30 min contact with 0.5 mg/liter residual chlorine while 16% of the coliphages remain.

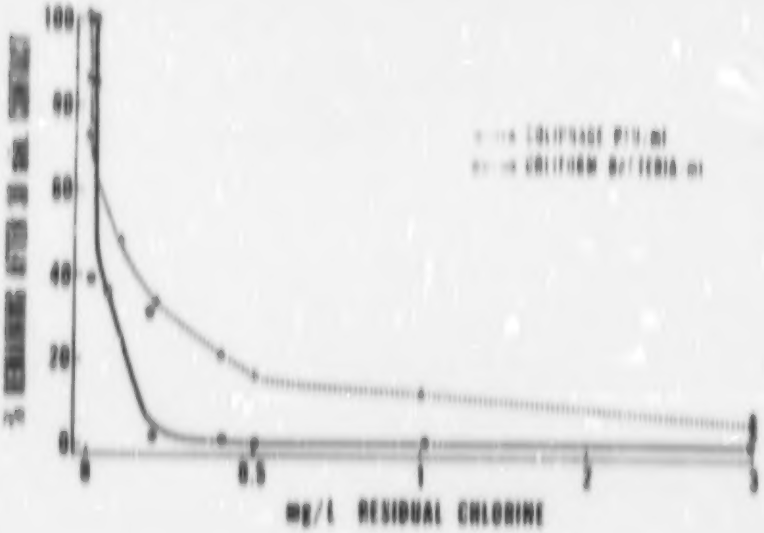

Figure 1. Inactivation of naturally-occurring coliphages and coliform bacteria in sewage effluent by residual chlorine.

Figure 2 indicates the effect of contact time on inactivation of coliform bacteria and coliphages. From Figures 1 and 2 it is evident that when coliphages have been reduced by approximately 80%, coliforms have been completely eliminated. After 60 min contact time, 12.5% of the coliphages remain. This is comparable or slightly better survival than that reported by Shah and McCamish (1972) for coliphage f2 and for poliovirus. It is possible that this 12% of highly resistant coliphages represents the predominating coliphage type in the sewage.

The effect on virus survival of removal of particulate matter from seawater is shown in Figure 3. Samples of natural and autoclaved seawater were filtered through cellulose acetate membranes (Millipore Filter Corp.) of various pore sizes, then seeded with virus. LOT was measured 5 days after seeding. LOT was less in natural seawater filtered through 0.8 and 0.65 μm membranes. High LOT occurred in the 0.45 μm filtrate followed by increasing titer in samples passed through smaller porosity filters. This pattern was constant in six different samples collected at various times during the year. Autoclaved seawater showed the same high LOT after passage through 0.45 μm filters.

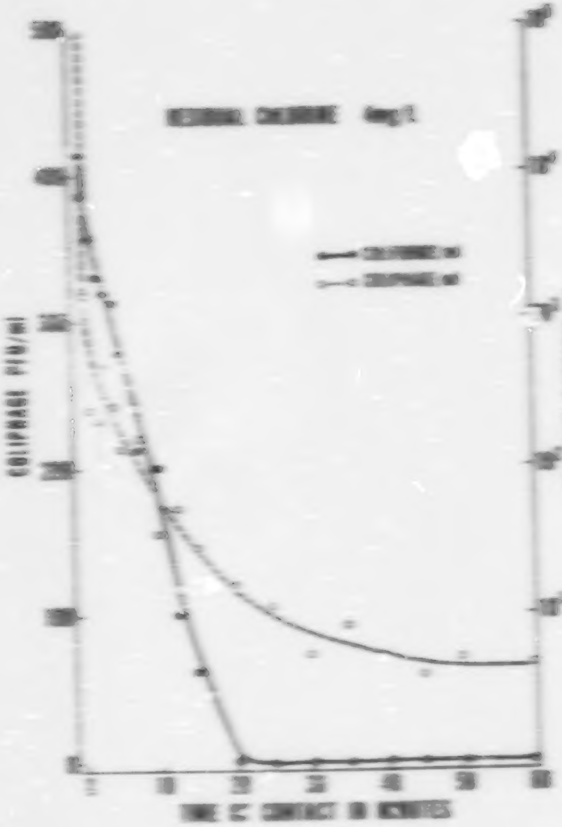

Figure 2. Effect of contact time on coliform bacteria and coliphage in sewage effluent

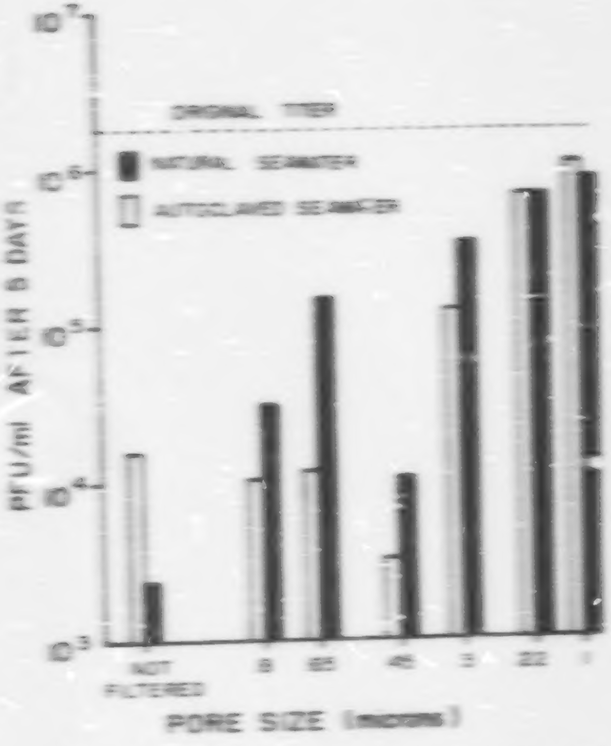

Figure 3. Loss of viral titer in natural and autoclaved seawater filtered through membranes of various porosities

Figure 4 indicates increasing LOT as artificial seawater samples are passed through smaller filters. It appears that particulate matter, which in some way is protective for the virus, is being removed by progressively smaller filters. Particulate matter in these samples could originate from dust, bacterial debris in the salts used, the flasks, or in the distilled water. This also indicates that the results shown in Figure 3 are not an artifact of filtration alone.

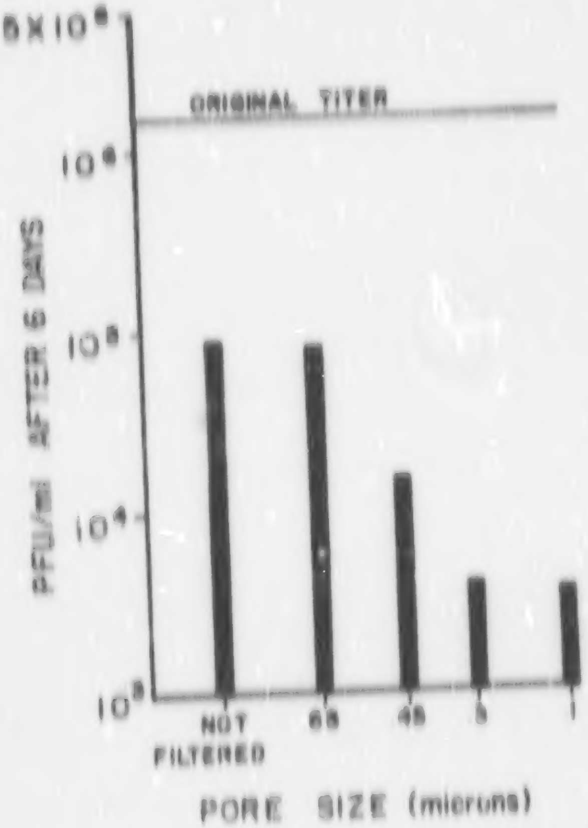

Figure 4. Loss of viral titer in artificial seawater aliquots filtered through membranes of various porosities

To further test this hypothesis, a sample of autoclaved seawater was divided into equal aliquots. Two aliquots were centrifuged at 30,200 G for 2 hr and two others for 5 hr at this speed. The resulting pellets were resuspended in equal volumes of autoclaved seawater. An additional sample of autoclaved seawater was filtered through a 0.45 um membrane. Finally, one sample was left untreated and served as a control. Results [illegible] summarized in Tables 1 and 2. High LOT occurred after the sample was centrifuged for 2 hr, but is not evident after 5 hr of centrifugation. It seems that a particulate causing high LOT has been removed after 5 hr but not after 2 hr. The LOT in the sample containing the resuspended 5-hr pellet was also high, whereas the resuspended 2-hr pellet was more similar to the control. This serves to strengthen the hypothesis that the particulate responsible for high LOT had been removed after 5 hr of centrifugation. The LOT was considerably lower than in the control when the 2-hr pellet was resuspended in artificial seawater. This could be due to large particulates which are protective for the virus. Greater LOT resulted from resuspending the 5-hr pellet in artificial seawater, showing that in this case the particles causing rapid LOT are still active. These results indicate the presence in seawater of at least two particulates affecting virus survival, i.e., a larger particle that is protective, and a smaller one that is antagonistic.

Table 1. Effect of particulates on loss of viral titer in autoclaved seawater

Treatment	Viral titer after 5 days ($\times 10^3$)[a] (PFU/ml)
None	190
Filtered through 0.45-μ porosity membrane	28
Centrifuged 2 hr at 30,200 G	60
Centrifuged 5 hr at 30,200 G	200
Pellet from 2-hr centrifuged sample resuspended	150
Pellet from 5-hr centrifuged sample resuspended	67

[a]Original titer was 9.0×10^5 PFU/ml.

Table 2. Effect of particulates on loss of viral titer in artificial seawater

Treatment	Viral titer after 5 days ($\times 10^2$)[a] (PFU/ml)
None	29
Resuspended pellet from autoclaved seawater centrifuged for 2 hr at 30,200 G	7,100
Resuspended pellet from autoclaved seawater centrifuged for 5 hr at 30,200 G	430

[a]Original titer was 9.0×10^5 PFU/ml; pH was adjusted to 8.1 in all samples with borate buffer.

In estuaries much of the suspended solids are composed of clay particles brought in by rivers and land runoff (Reid, 1961). Kaolinite is one of these clays commonly found in estuaries. Settling of these suspended solids forms estuarine sediments. Viral LOT was determined for various concentrations of kaolinite in seawater.

As shown in Table 3, as little as 5 mg/liter of kaolinite markedly decreased viral LOT. Natural seawater required a higher concentration of clay to produce a change in LOT. Flasks of natural seawater and artificial seawater, with and without added kaolinite, were assayed for LOT for approximately one month and produced the LOT curves shown in Figure 5. The protective effects of the clay are quite obvious.

Table 3. Loss of viral titer in kaolinite suspensions of artificial and natural seawater

Solution	Kaolinite (mg/ℓ)	Titer after 6 days (x 10^3)* (PFU/ml)
Artificial seawater	0	55
	5	171
	50	2,320
	500	5,890
Natural seawater	0	4
	5	1
	50	10
	500	1,500

*Original titer was 1.56 x 10^6 PFU/ml; pH in the artificial seawater was adjusted to 8.1 with borate buffer.

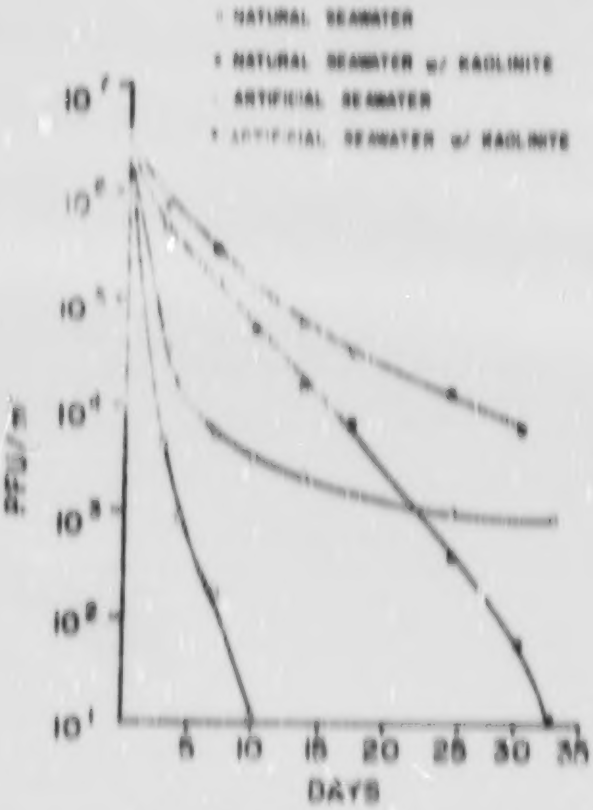

Figure 5. Loss of viral titer in natural and artificial seawater with and without 500 mg kaolinite/liter

The possible absorption by the kaolinite of substances toxic to the virus was then investigated. Kaolinite clay that failed to pass through a 0.65 µm membrane was collected and used to prepare a suspension containing 500 mg/liter clay in distilled water. One-hundred-milliliter aliquots of this suspension were autoclaved, centrifuged, and the kaolinite pellets resuspended in equal volumes of natural and artificial seawater and 0.45 µm filtrates of natural seawater. Two suspensions were prepared in the 0.45 µm filtrates and two in artificial seawater. One each was mixed on a shaker for 30 min, following which the clay was removed by filtration through a 0.65 µm filter. This process should eliminate the kaolinite along with any substances absorbed by the clay. Tables 4 and 5 show the LOT in each of the samples. The kaolinite seems to sorb the agent responsible for high LOT in natural seawater, shown by protection of the virus after removal of the clay. Yet, the LOT in artificial seawater in which the clay was not removed was one log less than that with clay (Fig. 5). The protective effect here then does not seem to be due to sorption of toxic substances, but is more likely due to adsorption of the virus leading to structural stabilization and protection.

Table 4. Effect of kaolinite on loss of viral titer in natural seawater

Treatment	Viral titer after 5 days ($\times 10^3$)* (PFU/ml)
None	1
Containing 550 mg/liter of kaolinite	280
0.45-µ filtrate	54
0.45-µ filtrate with 550 mg/liter of kaolinite	1,200
0.45-µ filtrate with 550 mg/liter of kaolinite removed	1,000

*Original titer was 2.0×10^6 PFU/ml.

Table 5. Effect of kaolinite on loss of viral titer in artificial seawater

Treatment	Viral titer after 5 days ($\times 10^4$)* (PFU/ml)
None	10
With 550 mg/liter of kaolinite	600
With 550 mg/liter of kaolinite removed	12

*Original titer was 1.0×10^7 PFU/ml.

Ocean water varies in pH and salinity from fresh waters. Since studies of virus adsorption to clays have usually been carried out in solutions within the range of ionic strength and pH of fresh waters (Carlson et al., 1968) it was possible that conditions in seawater might radically affect adsorption behavior. Figure 6 indicates degree of virus adsorption to varying amounts of kaolinite in artificial seawater. As noted, a small amount of clay adsorbs a large percentage of the total virus population.

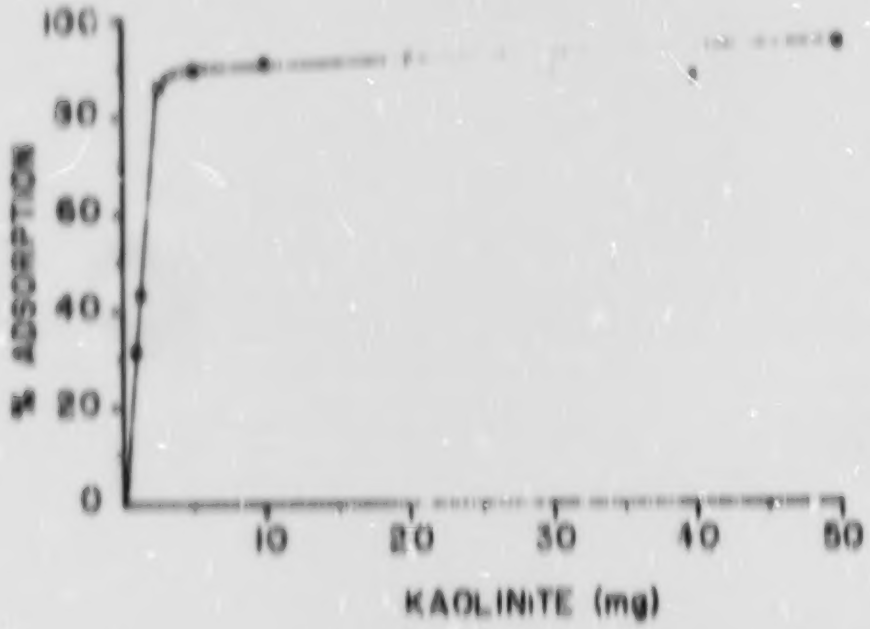

Figure 6. Adsorption of virus (10^8 PFU) to various concentrations of kaolinite in artificial seawater

Virus adsorption at varying salinities was then investigated and is shown in Figure 7. Changes in seawater pH effected changes in virus adsorption below pH 7.0; above pH 7.0 changes in adsorption were not significant (Table 6). In a natural estuarine situation there may be variations in pH and salinity due to tides, rainfall, etc., but it appears that these effects may not significantly alter viral adsorption. The presence of viruses adsorbed to sediments is not to be ignored since adsorbed viruses have been shown to be infective (Schaub, 1972). Deadsorption of virus was also brought about by increasing the concentration of organic matter or lowering the ionic strength. After adsorbing virus to kaolinite in natural and artificial seawaters, as described previously, one-ml samples were transferred to distilled water, artificial seawater, and artificial seawater with 80 mg/liter of nutrient broth. Kaolinite was removed by centrifugation and the supernatants assayed for deadsorbed virus. Deadsorption was brought about by both low ionic strength and by the presence of organic matter, but not by the same high salt concentration in the natural and artificial seawaters.

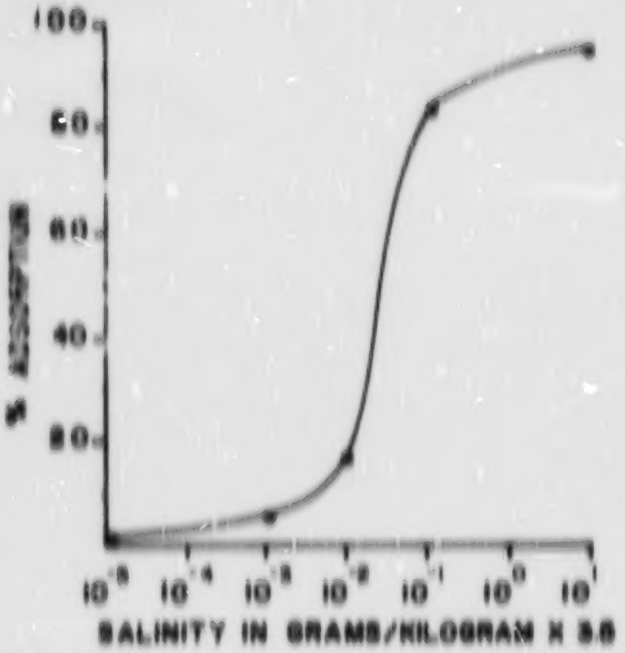

Figure 7. Adsorption of virus (10^6 PFU) to 50 mg kaolinite in artificial seawater solutions of various salinities

Table 6. Virus adsorption to 50 mg kaolinite at various hydrogen ion concentrations in artificial seawater

pH	Percentage of virus adsorbed*	Buffer
6.0	46	None
7.0	90	None
8.1	94	Borate
8.9	80	Borate

*Of 10^6 viruses.

DISCUSSION AND CONCLUSIONS

Particles occurring in seawater include a variety of substances such as living cells, cell debris, silts, clays, detritus, etc. (Horne, 1969). Variations in size of particles, chemical composition, and concentration are known to occur depending on the season and location. All of these factors may affect the fate of viruses in ocean waters.

It has been demonstrated that the coliform test is not a reliable indicator of the presence of pathogenic viruses (Grabow, 1968). Since viruses are being discharged into the environment in waste treatment plant effluents, despite conventional chlorination, it is essential that a new or additional indicator system be established for surveillance of viral contamination of waters. Similarly, it is necessary to insure that waste treatment plants operate at maximal efficiency. High quality effluents, low in suspended solids and BOD, are easily disinfected by conventional chlorination (Table 7), thus reducing the discharge of microorganisms potentially dangerous to humans and other life forms in the receiving environment.

Table 7. Comparative virological data, one year average, for sewage treatment plants, Virginia Key and Marco Island, Florida. Number of *Escherichia coli* B virus PFU/ml in each of the stages of two sewage plants.

Sewage plant treatment stage	Plaque-forming units/ml	
	Virginia Key	Marco Island
Raw influent	1,500	2,142
Activated sludge	1,600	845
Concentrated sludge	50,300	--
Digested sludge	2,600	160
Digested and dried sludge (6 weeks)	--	0
Final effluent	1,600	115
Oxidation pond	--	27
Chlorinated effluent	77	0
Overall efficiency of removal of suspended solids and BOD	60-65%	90-96%

Since seawater contains a variety of types of suspended matter, it is likely that virus-particle interactions may be equally diverse. The behavior observed in the filtration and centrifugation experiment discussed here may be explained as a selective segregation of two types of marine particles, one protective and a smaller antagonistic one. This antagonism does not seem to be enzymatic since it persists after autoclaving of the sample. LOT due to particulates may be attributed to virus attachment to sites with chemical groups that mimic the site of virus attachment to host cells. A second possibility may be that LOT is due to viral aggregate formation (Gerba, 1973; Akin, 1971), with particulate matter of certain size serving as nuclei for virus aggregates which then result in falsely apparent inactivation.

The fact than an inorganic clay like kaolinite could extend the persistence of the virus in seawater is of considerable public health importance. The possible transmission of disease to the exposed fish and shellfish populations is largely unknown at the present time.

In these studies it was observed that virus deadsorbs from the clay in the presence of organic matter. Therefore, the lower percentage of the virus adsorbing to clay in natural seawater compared with artificial seawater may be ascribed to the presence of soluble organic matter in natural seawater. In addition, it seems that a single clay particle is quite capable of adsorbing a multiplicity of virions, thus reducing the number of infective loci in the environment. However, ingestion of these virus aggregates may increase the probability of infection of susceptible individuals because of the larger dose of virus. Thus, viruses and other microorganisms entering coastal waters may readily adsorb to particles that prolong their survival. Settling of these particles creates a field of bacteria and viruses (De Flora et al., 1975) that may be released into the water by wave action.

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RELATIONSHIP OF MARINE POLLUTION TO HUMAN HEALTH

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It is a pleasure to speak to you today regarding the "Relationship of Marine Pollution to Human Health." The human environment clearly contains a multitude of chemicals in various forms. The possibility of such agents acting together to cause effects that may be additive, synergistic, antagonistic, or independent is always present. There are, however, limits to our ability to describe or to understand such interactions.

It is recognized by those concerned with human health that sources of information exist that have been often ignored in the past. Scientists engaged in studies of non-human, ecologic systems at the laboratory bench and in the field have gathered information regarding biological systems that has pertinence to humans. Ultimately, it is a truism that biological systems, from the bacterium to man, operate in similar modes throughout one spectrum of life. Conversely, the data developed from study of mammalian and other genera by the toxicologist can serve some of the information needs of ecologic toxicologists. The much needed interchange of knowledge between these two interested groups is only now beginning and should intensify.

There is a clear need to better define the scope and goals of the area called "marine biomedicine" and its relationship to other aspects of marine sciences. The subject areas can be represented by: (1) Marine Species as Models for Human Disease, (2) Human Health and the Marine Environment--Infectious Agents and Naturally Occurring and Foreign Toxins, and (3) Environmental Carcinogenesis.

MARINE SPECIES AS MODELS FOR HUMAN DISEASES

Marine biology and the great diversity of marine organisms represent a large unused potential for the provision of models that would be helpful in the study of human disease. Marine organisms possess a vast repertoire of adaptations valuable as models for study of human metabolism and its disorders. Models are important because the simplicity of their structural or metabolic specialization permits study of a single problem or function at a time. In contrast, the human or laboratory mammal often conceals its functions by the complexity of its interrelationships.

Marine organisms are beginning to yield comparable dividends for students of the nervous system. Thus, some of the complex interactions of neurons and neurotransmitter systems that spell psychiatric and neurologic disease in man are beginning to be unravelled through systematic study of the simpler circuitry of marine invertebrates and fishes.

Some scientists predict that the next approach will begin to yield secrets of the endocrine system. Already several published reports suggest a profitable switch to a phylogenetic approach for study of endocrine regulation.

"Sekoke," a syndrome virtually identical to diabetes mellitus, occurs among carp in Japanese fish farms, due to the fact that the carp are fed silkworm pupae rich in unsaturated fatty acids. The disease has been produced experimentally by simply feeding fatty acids and can be prevented by pre-treatment with the antioxidant vitamin E. This model provides an extraordinary opportunity to manipulate metabolic regulators by dietary changes.

Spectacular neurohormonal relationships have been described in migrating Pacific salmon. During migration from the ocean to fresh water upriver for spawning, the fish developed a rapidly progressive adrenal hypercorticism with many features of Cushing's Disease, hyperlipidemia and extensive arteriosclerosis.

It is a well known and extremely useful fact that fundamental characteristics of normal healthy nerve cells from creatures as diverse as man, mollusks and medusae are virtually identical. Indeed, an understanding of most basic nerve cell electrical phenomena has been gained almost exclusively from animals such as the squid. The fact that certain disease conditions of the brain cells of man are recognizable in the neurons of very simple organisms is nowhere near so widely recognised or utilised. For example, the convulsive bursts of electrical impulses that occur in primates suffering from various forms of epilepsy can be elicitud from the neurons of sea slugs.

HUMAN HEALTH AND THE MARINE ENVIRONMENT--INFECTIOUS AGENTS AND NATURALLY OCCURRING AND FOREIGN TOXINS

Shellfish such as clams, mussels, oysters and scallops that feed on poisonous dinoflagellates become very poisonous; when these shellfish are consumed by men, a paralytic disease results that is severe and may cause death within a few hours.

There are other poisonous dinoflagellates that produce poisons of a different nature. One of these is the organism that causes the destructive red tide along the Florida coasts. Blooms of this organism result in massive fish kills. Compound(s) produced by these organisms are aerosolized by the ocean spray and cause respiratory disturbances in people along the coast. The chemical nature of these poisons is not well established.

There are problems arising from the fact that filter-feeding shellfish take up and retain bacteria and viruses and, therefore, become disease vectors for man. These animals feed by selectively filtering and concentrating small particles of matter from large quantities of water. Among the particles concentrated, and subsequently ingested, are bacteria and viruses capable of producing disease in humans.

Filter-feeding shellfish may not be the only organisms capable of accumulating and retaining bacteria and viruses. Recent investigations have shown West Coast crabs also are able to accumulate viruses either directly from polluted water or from feeding on contaminated shellfish. Viruses can survive in crabs processed by simple boiling. Accumulated viruses will survive in contamiuated chilled or frozen samples of edible crabs for periods of five days to one month depending upon storage temperature. To date there have been no confirmed reports linking crabs to viral diseases, however crabs and shrimp have been implicated as vectors in outbreaks of gastroenteritis caused by the bacterium *Vibrio parahaemolyticus*.

Movement of metals, and their relocation in advanced industrial societies, represents a major environmental problem. The movement of mercury alone has caused major disasters in Japan, Pakistan, Iraq, Sweden, Canada and the United States. The incidents in Japan and Iraq have resulted in the death or irreversible mental illness of over 4,000 people. In order to fully understand the movement of toxic metals through geochemical cycles into biological cycles, followed by bioaccumulation and toxicity in the central nervous systems of higher organisms, it is important to understand the general principles of how metals are translocated.

ENVIRONMENTAL CARCINOGENESIS

In studying carcinogenesis, three steps of identification are necessary: (1) identification of carcinogenic activity of selected chemicals by *bioassay*; (2) identification, development, and selection of biological *models* for carcinogenesis bioassays as well as for the characterization of carcinogenesis processes; and (3) identification of *processes* required for the carcinogenic action of selected agents as target points for corrective measures.

The effective development of such studies depends in part on the availability of appropriate animal models capable of reproducing tumor types analogous to those observed in man. The development of such biological models is particularly important for establishment of selectively sensitive bioassay systems. An important phase is the selection and standardization of bioassay systems that can be reproduced under strictly controlled standardized conditions.

A chemical hazard to man and animals may manifest itself in the development of mutations, congenital anomalies and cancers which appear only after long latency periods. Without obvious clusterings of diseases in space and time, an increase in their frequency can be readily missed. Thus, preventive measures can only be introduced at times when large population segments are irreversibly affected. Recent observations indicate that marine organisms can provide sensitive and useful models for studies of this important problem area.

The use of easily detectable skin tumors among bottom-feeding fish as an early and economical warning device is being considered and its feasibility in a large-scale monitoring program is being explored. The extent of contamination of marine organisms and sediments by carcinogenic and mutagenic polycyclic aromatic hydrocarbons (PAH) has been examined by isotope dilution and gas chromatographic techniques. The degree of contamination of mussels by benzo(a)pyrene is closely correlated with the degree of human activity in the vicinity of the sampling site. Elevated levels of b(a)p have been reported in sediments near a sewage outfall. Motorboat marinas and creosoted wharf structures appear to represent major sources of hydrocarbons in the marine environment. Therefore, measurement of benzo(a)pyrene in mussels, which are ubiquitous and easy to sample, may be very useful in a large-scale screening program for carcinogens in the marine environment.

In the marine habitat, white croakers feeding near sewage outfalls along the southern California coast are subject to oral epidermal papillomas while croakers collected away from the sewage discharge areas do not have such tumors. While this example suggests that there is a carcinogen in the sewage, no such agent has been identified.

There are cancers caused by viruses, i.e., Herpes viruses cause or have been linked to Marek's lymphoma in chickens and cold sores, mononucleosis and Burkitt's lymphoma in people. The leopard frog renal adenocarcinoma should be an excellent model to determine how Herpes viruses cause cancer. The tumor occurs in very high incidence, is transplantable, and the virus is easily harvested.

Also, marine animals have interesting possibilities for studying the influence of selected immune factors on tumorigenesis. "B" lymphocytes produce fewer immunoglobulins as the phylogenetic scale is descended from mammals through amphibians, bony fish, cartilaginous fish and jawless fish. In invertebrates, there are no "B" lymphocytes.

SUMMARY

Some toxic substances, carcinogenic compounds or biological agents are concentrated in invertebrates and lower vertebrates suggesting the possibility that these compounds could be transferred through the food chain to humans. A good example of biological magnification occurred when Japanese fishermen developed mercury poisoning from consuming fish from Minamata Bay.

It is clear that we must develop superior methods to screen new chemicals for toxicity, especially since less than one-half of the new chemicals that go into major production are screened for carcinogenicity. This is no doubt due to the excessive cost and other requirements of rodent and primate test systems. Various lower animals offer many possible advantages of sensitive and clearcut responses to carcinogens and/or mutagens, because of natural cloning, simple genetics due to a relatively small genome, easy low-cost maintenance, etc.

In my opinion, the development of marine biomedicine will not be realized unless biomedical scientists, knowledgeable about human health problems, learn more about marine biology. Similarly, marine biologists, knowledgeable about the great variety of creatures of the sea, must learn more about biomedical problems and needs. Both will suffer if as scientists we fail to initiate integrated studies of the marine biota and human health.

DEVELOPMENT OF METHODS FOR RAPID DETECTION OF TRACE METALS IN SEA WATER

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ABSTRACT

In unpolluted natural waters heavy metal ions are present in very low concentrations, about one microgram/liter. Higher concentrations, caused by waste disposal, sometimes surpass permissible toxic levels, causing serious changes in eco-physiological equilibria of organisms in natural aquatic systems (rivers, lakes and seas). Because of their selectiveness, simplicity and high sensitivity, electrochemical methods, especially polarography and related techniques, are promising for determination of trace metals in natural and polluted waters.

Applications of advanced techniques of electrochemistry in aquatic chemistry are still in the beginning stage. However, these methods will eventually play an important, or perhaps the key, role in determination, speciation and characterization of metal traces and microconstituents of fresh and sea water. This should contribute greatly to elucidation of mechanisms and biogeochemical pathways of microconstituents (and pollutants) in the aquatic environment.

DESCRIPTION OF THE RESEARCH

The proposed research project concerns physicochemical characterization and study of the fate of heavy metals as pollutants in natural waters.

Most elements in the periodic table are metals. Some are highly toxic, especially heavy metals, whose natural concentration level in sea water and other natural waters is usually lower than 20 ppb. Many are industrially produced in large quantities and are also common pollutants (FAO, 1970).

The actual physicochemical forms of heavy metals released in natural aquatic systems change simultaneously with changes in physical and chemical conditions of the medium. Thus, the composition of natural waters and waste waters has a strong influence on the fate of released heavy metals because of their hydrolyzation and possible interactions with organic and inorganic particles as well as with dissolved organic complexing substances and inorganic ions.

Lead, cadmium, zinc, and copper were selected as representatives of metals which are considered, for different reasons, to be potentially harmful to the aquatic environment.

Lead and mercury are the most threatening pollutants. The concentration of these heavy metals in the ocean surface water in the northern hemisphere has increased considerably above natural concentration levels.

Use of tetraethyl lead in gasoline is the main reason for the increase of lead in the environment (Patterson, 1971). Cadmium, known as a potent toxicant, is used in considerable quantities in plastics and battery industries, the products of which sooner or later become waste (Yamagata and Shigematsu, 1970; Anonymous, 1971). Zinc and copper (with world production as high as 5 x 10^6 tons/yr) as biogenic elements accumulate to a considerable extent in edible organisms from water (Bowen, 1966; Branica, 1970).

The biogeochemical cycle of a particular pollutant (rate of accumulation and pollution, and most importantly the degree of danger to man) depends strongly on its concentration and actual physicochemical state and reaction pathways of the pollutant in natural water systems. The determination of such physicochemical states and the clarification of reaction pathways of the pollutant in question should help considerably in understanding the mechanism of heavy-metal pollution.

Simultaneous existence of polluted and unpolluted areas in close proximity is a very important factor in field research. Geographical areas to be considered by the project are: (1) The fresh water system around the city of Zagreb (metropolitan area population about 1 million) includes the Sava River (mean flow for 1951/1970 about 320 m^3/sec) and its tributaries (Kupa, Korana, Krka and Sutla), which are unpolluted as near as 20-30 miles from Zagreb; and (2) the northern Adriatic (average depth less than 30 m with maximum depth of approximately 50 m) is a shallow basin under strong influence from the heavily polluted Po River, several ports (Venice, Trieste and Rijeka), and other cities along the coast (FAO, 1972).

RESEARCH OBJECTIVE AND APPROACH

The major objective involves characterization of the physicochemical state of some traces of heavy metals (Pb, Zn, Cd and Cu) in the northern Adriatic and in the fresh water around the city of Zagreb.

Determination of the actual physicochemical state and the mechanism and rate of chemical transformations between various species of the pollutant is of primary interest and even more important than analytical determination of the total amounts of pollutants in the environment. The characterization includes determination of species distribution (ionic, hydrolysed, chelated and submicroscopic solid particles) in natural waters. Also included is development of appropriate analytical procedures to enable detection of specific metals at natural and polluted concentration levels.

The knowledge gained through analytical determination and characterization of heavy metals will be used to predict effects of increased release of heavy metals into the environment and to offer new solutions in wastewater treatment for diminishing harmful environmental effects.

In the laboratory for physicochemical separations of the Center for Marine Research, electrochemical techniques, which have many advantages in comparison with other methods, are developed. At the same time the laboratory is strongly oriented toward development and application of electroanalytical techniques suitable for direct determination and characterization of microconstituents in natural waters (Barić and Branica, 1967; Branica et al., 1969; Maljković and Branica, 1971).

DEVELOPMENT AND APPLICATION OF ELECTROANALYTICAL METHODS

The electrochemically studied substance is either reduced or oxidized at a working electrode exchanging n electrons per elementary step in the electrode reaction:

$$\mathrm{Ox} + ne^- \rightleftharpoons \mathrm{Reduction}$$

In polarography and voltammetry the corresponding current-potential curve is recorded. The electrode potential E is controlled and the current i is the measured quantity. The working electrode is always a microelectrode. For analytical applications, mercury, or at least mercury-coated, electrodes have the advantage of a homogeneous phase, and smooth surface with a rather high hydrogen over-voltage, resulting in high reproducibility.

Sea water is a good supporting electrolyte for polarographic and voltametric measurements due to its high ionic strength (I = 0.7) (Branica et al., 1968). After deoxygenation the sample can be directly analysed without additional pretreatment.

For direct determinations of metal traces in sea water extremely sensitive techniques (with reasonable precision and selectivity) are demanded. Only more advanced electroanalytical techniques offer sufficient sensitivity for direct measurements and determinations. For this purpose even the most advanced methods must be utilised frequently to the limits of their sensitivity potentialities, which means, of course, some sacrifice in precision.

Sensitivity and selectivity of electroanalytical methods have been developed in two directions: (1) improvement of instrumentation (applying excitation potential of different forms and increasing sensitivity and selectivity of current response) and (2) construction of new electrodes (after DME, HMDE, CMGE, RMGCE, T-RMGCE, etc.).

In Table 1 the maximum sensitivity obtained by different combinations of instruments and electrodes is compared.

Table 1. Maximum sensitivity (expressed in mol/liter) of electrochemical methods for typical electrode reaction $\mathrm{Me}^{2+} + 2e^- \rightleftharpoons \mathrm{Me(Hg)}$

Applied technique	DME	HMDE	CMGE	RMGCE	T-RMGCE
D.C. polarography	10^{-5}	2×10^{-8}	5×10^{-9}	2×10^{-9}	–
Diff. voltametry	10^{-6}	(c)	(c)	–	10^{-11}
Oscilo-polarography	10^{-6}	5×10^{-9}	2×10^{-9}	(a)	(c)
Square-wave polarography[b]	10^{-7}	10^{-9}	(a)	(a)	–
Pulse polarography	5×10^{-8}	10^{-10}	10^{-10}	2×10^{-11}	(c)

[a] very high capacity current. [b] only for reversible electrode reactions. [c] not investigated up to the present.

Advantages and limitations in use of polarography and related techniques (connected with particular types of instrumentation) and characteristics of several types of working electrodes will be discussed in detail. Application of electroanalytical techniques in marine chemistry has been recently reviewed (Whitfield, 1975; Nürnberg and Valenta, 1975).

Electrochemical techniques have been used for characterization of some metal ions in systems similar to sea water (Barić and Branica, 1967, 1969; Maljković and Branica, 1971). Although the sensitivity of these techniques is relatively low, measurements were made at a concentration level higher than that of natural sea water. A modification of ASV with HMDE was developed for determination of the ionic state of cadmium naturally present in sea water (Bubić and Branica, 1973).

The application of the recently proposed electroanalytical procedure for characterization of ionic forms of trace metals with HMDE (Bubić and Branica, 1973), extended by the use of the rotating thin mercury film electrodes (MCRGCE), will be discussed. The theoretical current-voltage and peak current-deposition potential curves are in fairly good agreement with experimental curves obtained with MCRGCE even at very low trace metal concentrations. Correlation between the polarographic half-wave potential $E_{1/2}$ and the potential of the half height of the polarogram-like anodic peak current vs deposition potential curves ($E^{*}_{1/2}$) has been found. This relation makes possible the study of metal complexations by the method of DeFord and Hume (1951) at very low concentration levels on the basis of $E^{*}_{1/2}$ shifts instead of "classical" $E_{1/2}$. By this approach some trace metals in unpolluted natural waters at the actual concentration can be characterized. For example, the ionic state of lead naturally present in sea water (10^{-8}M) has been studied and the results are compared with the classical D.C. polarographic measurements at the concentration of lead at the 10^{-4}M level.

During previous years, over 1,300 sea water samples from the Adriatic Sea were analyzed in our laboratory for ionic zinc, cadmium, lead and copper content. During the cruise of the research vessel *Vila Velebita* (1973/74) the average concentration (Bubić et al., in press) of the investigated metal ions was found to be: (1) 14 µg Zn/liter, 0.1 µg Cd/liter, 0.7 µg Pb and 1.2 µg Cu/liter at surface layer, and (2) 6 µg Zn/liter, 0.1 µg Cd/liter, 0.6 µg Pb/liter and 1.1 µg Cu/liter in waters deeper than 5 m. These values are not significantly different from the ones reported in shore waters from other locations. Only in the case of zinc do the results indicate specific seasonal, horizontal and vertical distribution. This could be due either to a very high rate of biogeochemical activity or to high urban pollution, which is strongly influenced by seasonal touristic movements.

CONCLUSION

Electrochemical methods are very convenient for determination of concentration of trace metal ions in sea water due to their high sensitivity, simplicity of procedure and relatively cheap instrumentation. The sensitivity limit of the particular method depends on the excitation and measuring technique and the type of working electrode used.

In addition to quantitative aspects, it is also possible to characterize the physicochemical state of ionic species in natural and polluted sea water. This is of particular importance for investigation of basic biogeochemical processes. These methods could be used in delimitation of mechanisms and in defining relationships between the basic parameters and pathways in biogeochemical cycles of the particular metal in natural and polluted aquatic systems.

FUTURE PLANS

The proposed research program includes: (1) characterization of the physicochemical state of heavy metals (Pb, Cd, Zn, Cu and others) which are of primary interest in pollution of natural aquatic systems; studies will cover determination of total amount and distributions of various species in fresh, brackish and sea water; and (2) investigation of the mechanism of physicochemical processes of heavy metals after discharge into natural waters and the influence of the physicochemical form of the pollutants at the time of discharge on their fate in natural waters.

To meet these goals various electrochemical methods will be developed and used, as follows: determination of lead, cadmium, zinc and copper distribution in natural waters, in the northern Adriatic and in fresh waters at various stations in the vicinity of Zagreb; development of methods and physicochemical characterization of lead, cadmium, zinc and copper in natural waters; investigation of chemical processes of mentioned metals under various conditions (ionic strength, pH, chelating agents, etc.) and at the concentration level found in natural waters; and the influence of organic matter (dissolved and suspended) on the fate of heavy metals in natural waters.

To fulfill this program it is necessary to develop additional analytical methods for determination of lead, cadmium, zinc and copper at very low concentration levels (10^{-7} M–10^{-10} M); to investigate the hydrolysis of mentioned metals and complexation with different inorganic and organic ligands present in natural or polluted waters; and to study the effect of adsorbed organic substances on the electrode surface on mass and charge transport processes.

The following methods and techniques will be used: polarography (D.C. and A.C. polarography, square-wave polarography and pulse polarography); voltammetry (cyclic voltammetry, anodic stripping); micro-electroanalysis (potentiostatic and radiometric electrolysis, microcoulometry, electrolysis through ionic selective membranes, etc.).

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EFFECT OF LEAD ON DINOPHYCEAE

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ABSTRACT

The effect of lead on growth, chlorophyll "a" concentration and rate of uptake of radioactive carbon by *Prorocentrum micans* and *Scrippsiella faroens* was studied with intergeneric differences evident. So far as cell numbers and chlorophyll "a" concentrations were concerned no response to lead was shown by *Prorocentrum micans*; however, inhibitory effects of lead were visible in *Scrippsiella faroens*. Lead decreased rate of uptake of radioactive carbon by both species. In general the effect of lead on the two species was mild and therefore can be considered the less toxic heavy metal.

INTRODUCTION

In addition to industrial and municipal wastes, use of lead alkyls in gasoline is increasing the concentration of lead in the marine environment (Dryssen et al., 1972; Schulz-Baldes, 1972; Chow et al., 1973). Compared with copper, mercury and other heavy metals, fewer studies have been made on the effect of lead on aquatic plants (Malanchuk and Gruendling, 1973). Among marine plants, much work has been done on seaweeds (Clendenning, 1959; Bryan and Hummerstone, 1973; Hägerhäll, 1973) but marine phytoplankton have been relatively neglected. Knauer and Martin (1973) and Abdullah and Royle (1974) reported uptake of lead by marine phytoplankton in nature, and Riley and Roth (1971) and Lewin (1974) demonstrated the same to be true experimentally.

Lead has been shown as either effective or ineffective on the growth and metabolism of plants (Clendenning, 1958; Whitton, 1970a,b; Bryan, 1971), and Lewin (1974) has regarded lead as one of the less toxic of heavy metals. In any event, it passes through the food chain and may become toxic to higher trophic levels (Malanchuk and Gruendling, 1973). Portman (1972) has regarded lead as a cumulative poison to man, and its toxicity to marine animals has been reported by a number of workers (Brown and Ahsanullah, 1971; Schulz-Baldes, 1972). In view of a paucity of information on the effect of lead on phytoplankton, and its significance in the marine food chain, the following study was carried out. Two species of Dinophyceae (Dinoflagellates) *Prorocentrum micans* Ehrenberg and *Scrippsiella faroens* Paulsen were reared in separate cultures and the effect of lead on their growth, chlorophyll concentration, and rate of uptake of radioactive carbon was studied.

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MATERIAL AND METHODS

Stock Cultures. Stock cultures of *Prorocentrum micans* and *Scrippsiella faroens* were maintained in 5-liter narrow-mouthed bottles. The culture medium used consisted mainly of seawater collected from the northern part of Helgoland Bight; the samples were sterilised through a membrane filter (Millipore Corp.) (22 µ). A solution composed of 0.1 g $NaNO_3$, 0.02 g $NaH_2PO_4 \cdot H_2O$ and 3 ml of a very light soil extract, was prepared using a Soxhlet apparatus (Kornmann, 1973), and the preparation added to each liter of sterilised seawater. Finally, a trace amount of vitamin B_{12} was added to the medium. All cultures were illuminated from one side with fluorescent daylight tubes (6,000 lux) at the bottle faces. They were subjected to a daily rhythm of 14 hr of light (6 A.M. to 8 P.M.) and 10 hr of dark (8 P.M. to 6 A.M.). Temperature throughout was maintained at 15 C and the salinity of seawater ranged from 31.67 ppt to 33.33 ppt. Fresh stock cultures were made monthly.

Experimental Cultures. The experimental cultures were batch type and differed from stock cultures in lacking soil extract. A 30-40 ml aliquot of stock culture suspension was added to a 5-liter experimental medium. Cells thus incubated remained in lag phase for 2 to 3 days, after which the entire medium was divided into 5 portions of one liter each. One served as the control and in the remaining four varying amounts of lead were added in the form of lead nitrate to give concentrations of 25 µg, 100 µg, 500 µg and one mg per liter. The method of illumination and temperature was identical to that of stock cultures. The inoculated vessels were shaken vigorously by hand for one minute twice a day even though both species showed vertical migration by ascending during the day and settling during the night. Bubbling of air was avoided as it had been reported to convert dissolved matter into particulate matter (Riley et al., 1965). Cells were enumerated with an Utermöhl microscope.

All glassware and filter apparatus were autoclaved at 14 lb pressure before use and all nutrient media were made in sterilised distilled water. Double distilled water was used for preparation of metal solutions. Only one ml of each solution was added to give the required concentration in the medium. Cultures were not axenic.

Chlorophyll Measurements. Chlorophyll "a" was measured simultaneously with cell numbers in terms of in vivo fluorescence units employing a G. K. Turner Fluorometer. A 5-ml aliquot of the growing culture was taken in a vial, and directly measured on the Fluorometer over all ranges, namely 30X, 10X, 3X and one X, depending upon the concentrations of cells. The concentrations of cells after the end of the exponential phase were sometimes so high that their fluorescence exceeded the detection limit at all ranges; in such cases the sample was diluted 2-4 times before measurement on the scale. In this paper the in vivo fluorescence units are designated as chlorophyll "a" concentration.

Rate of Uptake of Radioactive Carbon. Photosynthesis was measured via rate of uptake of radioactive carbon. Fifty milliliter samples of growing cultures were taken in small light and dark glass-stoppered bottles, and incubated with one ml of 4 µc of sodium bicarbonate. The experiments were run for 4 hr under the same light and temperature conditions as the culture itself. After completion of incubation, samples were immediately filtered through cellulose nitrate filters. The latter were not dried but were immediately transferred to scintillation vials containing 20 ml scintillation fluor (2 parts toluol, 5% butyl PBD, one part ethylene glycol monoethylether). The filter papers were completely soluble in this combination. The scintillation vials were then exposed to continuous strong light for 24 hr bleaching out of pigment (Pugh, 1970). The vials were then processed on a Packard Tri-Carb model Counter for 4 min on 3 channels, and measurements corrected for blank and dark counts.

Discussion of Methods

In all experiments, a medium made basically from filter-sterilised seawater was preferred to synthetic medium, the main reason being its many similarities to natural seawater. In the present study this similarity is essential, as the observations in a modified medium could not be considered representative of the natural environment. Thus, filter sterilisation was used to retain as much of the natural quality of seawater as possible, with only 2 nutrients and one vitamin added to the medium. One major drawback was the unknown concentration of lead in seawater but this was measured each time seawater was used. However, no attempt was made to measure lead concentration as it has been reported to be very low in seawater (Abdullah and Royle, 1972; Knauer and Martin, 1973). To this author's knowledge, no information exists that Helgoland's waters have ever been polluted with lead. Dryssen et al. (1972) reported concentrations of lead in surface waters away from the industrialised coasts in the range of 0.07-0.4 μg/liter, which was many times lower than the lowest concentration used here. Measurement of such a negligible quantity would be of little value. Moreover, a number of studies showed that lead inhibits growth and metabolism of algae at ppm (mg) level (Whitton, 1970a,b; Bryan, 1971; Malanchuck and Gruendling, 1973). Lead was added to cultures only when cells had passed the lag phase so as not to subject them to the additional stress of a heavy metal. Lead nitrate was preferred to lead chloride because of its greater solubility (Schulz-Baldes, 1972; Carter and Cameron, 1973; Malanchuck and Gruendling, 1973).

No attempt was made to measure the actual concentration of chlorophyll "a" as the nature of the experiment required relative values rather than actual quantities. Therefore, in vivo fluorescence units were measured instead since this method is more sensitive, easier and rapid than actual measurement of chlorophyll itself. Tunzi et al. (1974) found that in vivo fluorescence units showed a close relationship to chlorophyll "a" concentration.

RESULTS AND DISCUSSION

No apparent decrease in cell numbers of *Prorocentrum micans* at any lead concentration was observed, even with inocula of different quantities (Fig. 1 and 2). Clendenning (1958) also reported no inhibition in growth of *Macrocystis pyrifera* even at a concentration of 4.1 mg/liter. The cells of *Scrippsiella faeroense*, however, decreased in numbers progressively with increase in concentration of lead (Fig. 3 and 4). Figure 5 shows the results of a 4-day experiment but it is apparent that, as in the other experiments, during the exponential phase of growth there were hardly any differences in cell numbers at all concentrations. The effect of lead was seen only at the end of the exponential phase at concentrations of 100 and 500 µg (Fig. 3 and 4). The effect at 25 µg was negligible. However, at the one mg level the results were different. With larger inoculum of cells at the start of the experiment (Fig. 4), growth inhibition was observed initially, whereas with smaller inoculum (Fig. 3) inhibition was noted at the end of the exponential phase. The use of inocula of different cell quantities also affected the time of recognition of lead's effect. Thus, with 720 cells at the start of the experiment the effect occurred sooner (4th day) than with 134 cells (7th day). This discrepancy could simply mean that with larger inoculum the exponential phase ended earlier than with smaller inoculum; the final yield of the exponential phase should be the same because identical culture conditions were used in both experiments. The effect of lead was obvious at the end of the exponential phase because the cells at this stage were physiologically weak (Fogg, 1965), as could be seen by the rate of cell division in the control. Moreover, the cells should have accumulated more lead at this stage than during the earlier phase as the process of accumulation is time dependent.

The problem remains of different responses of *Prorocentrum micans* and *Scrippsiella faroens* toward lead. The solution probably lies in the different modes of their cell division. In *Scrippsiella* the cell contents emerged from the theca in the shape of naked rounded masses through a partial rupture in the girdle region. During routine observations a number of empty theca, partly opened at their girdle regions, were seen. These masses of protoplasts were sometimes found moving slowly via the two original flagella attached. The protoplasts later elongated in size and divided to form daughter cells which developed their own theca. The mode of cell division of this species was very similar to that of *Peridinium trochoideum* (Braarud, 1958). As the cells at the end of the exponential phase grew weaker and accumulated more lead than in the earlier period, they were unable to exert sufficient pressure to rupture the theca and emerge, thus cell division was absent. This might be the reason for the observed decrease in cell numbers in this species.

Prorocentrum micans, however, divided differently from that described above. Here, cell division was followed by a longitudinal split along the suture into two halves so that each daughter cell carried one-half of the parental theca and developed the other by itself (Fritsch, 1948). Thus, there was no extrusion of cell contents out of the theca nor was its rupture probably as difficult as in *Scrippsiella*. This might explain why growth in cell numbers of *Prorocentrum* was not affected by lead. A large number of dinoflagellates divide similarly to *Prorocentrum* in the sense that cell contents do not eject out of the theca before cell division but remain inside. It is therefore worthwhile to determine if growth of such dinoflagellates remains unaffected by lead.

In general the chlorophyll "a" concentration measured in terms of in vivo fluorescence units (Tables 1-4) showed the same behavior toward lead as the cell numbers of both species counted simultaneously. This implies that the observed decrease in chlorophyll concentration was not due to the direct effect of lead but rather to decrease in cell numbers. To the author's knowledge, there is no evidence that lead is inhibitory to chlorophyll synthesis.

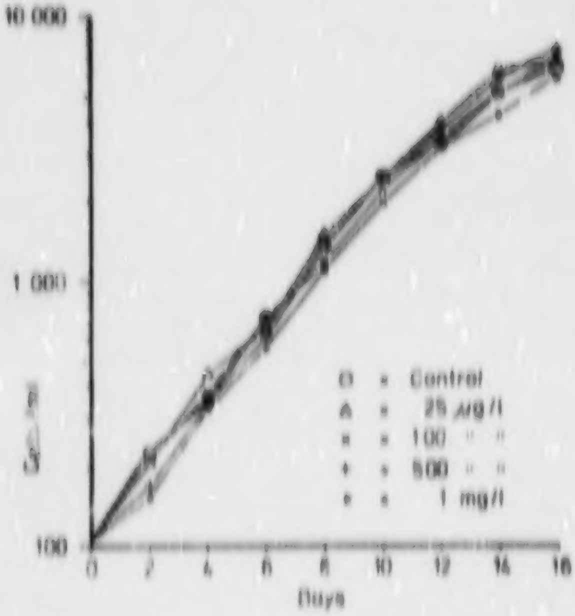

Figure 1. Effect of lead on growth of *Prorocentrum micans* (simultaneous measurements of chlorophyll "a" and uptake of radioactive carbon are shown in Table 1 and Figure 6, respectively)

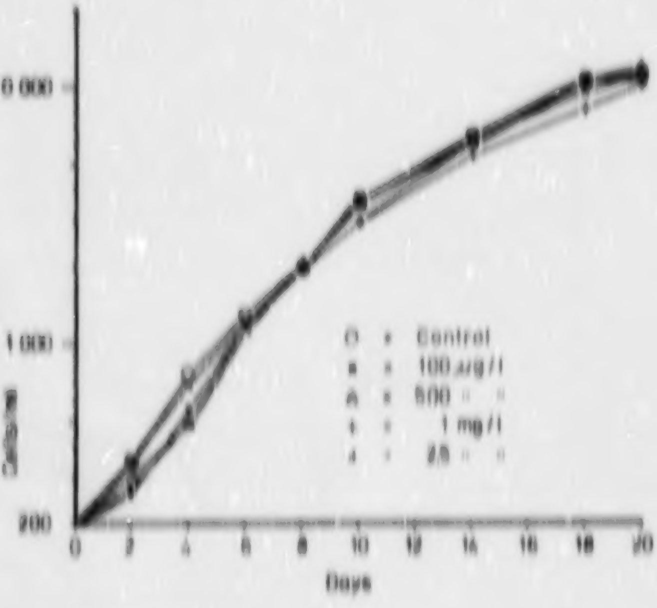

Figure 2. Effect of lead on growth of *Prorocentrum micans* (simultaneous measurements of chlorophyll "a" and uptake of radioactive carbon are shown in Table 2 and Figure 7, respectively)

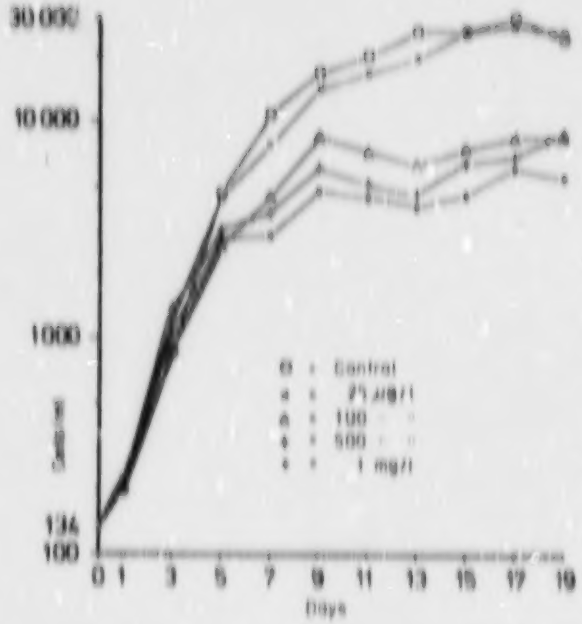

Figure 3. Effect of lead on growth of *Scrippsiella faroens* (simultaneous measurements of chlorophyll "a" are shown in Table 3)

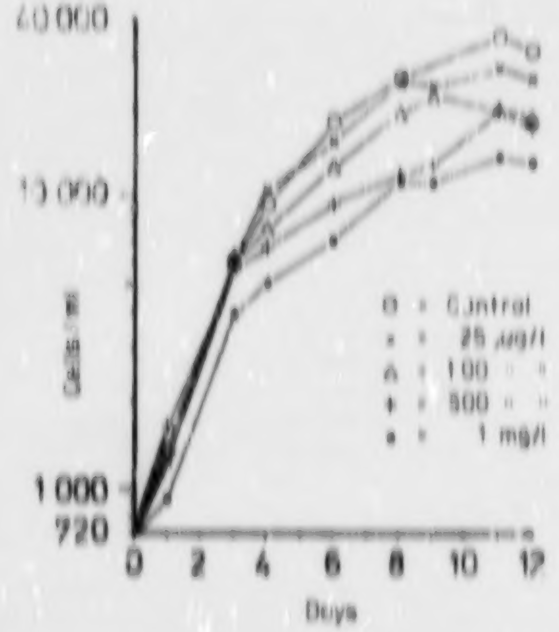

Figure 4. Effect of lead on growth of *Scrippsiella faroens* (simultaneous measurements of chlorophyll "a" and uptake of radioactive carbon are shown in Table 4 and Figure 8, respectively)

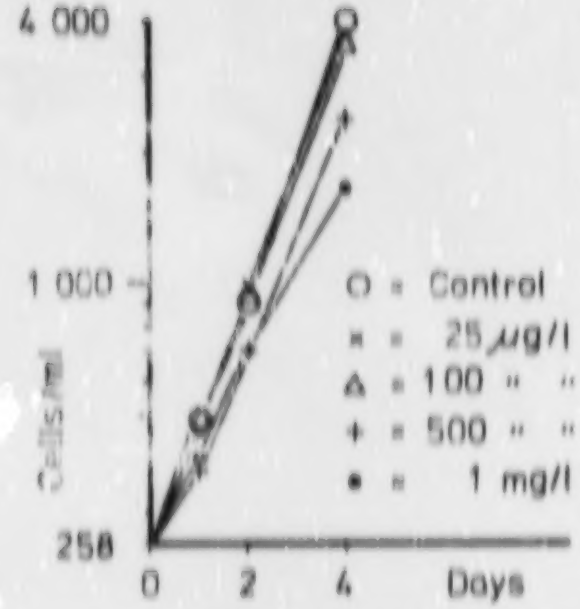

Figure 5. Effect of lead on growth of *Scrippsiella faroens*

From the foregoing it is apparent that lead either did not affect the growth of cells as with *Prorocentrum micans*, or affected it only moderately, as with *Scrippsiella faroens*. Thus, there was no complete inhibition in growth of *Scrippsiella* even at one mg lead and inhibition was only 20% of the control even after 20 days (Fig. 3). A number of workers also reported little or no effect on the growth of other marine organisms (Clendenning, 1959; Brown and Ahsanullah, 1971; Bryan and Hummerstone, 1973; Carter and Cameron, 1973). Monahan (1973) reported lead inhibition in growth of *Hormotila blennista* in phosphate- and potassium-free medium. In the presence of phosphate, lead was precipitated and therefore no inhibition in cell growth was observed. Koeppe and Miller (1970) also suggested that the effect of lead might be accentuated in absence of phosphates. However, inhibition in growth of *Scrippsiella faroens* was noted although phosphate was added in excess of lead. This implies that not all lead was precipitated by phosphates. Besides, Bryan (1971) reported that heavy metals adsorbed on both living and non-living particulate matter and chelation of cupric ions by extracellular algal products was also possible (Fogg, 1962). In all experiments with *Scrippsiella* and *Prorocentrum*, a very fine white precipitate was observed on the bottom of flasks containing one mg lead only after a few days following addition. With *Scrippsiella*, the precipitate had the shape of microscopic flakes in which a number of empty shells were found entangled. No type of precipitate was noted at lower concentrations. It is noteworthy that Portman (1972) reported the solubility of lead salts in seawater to approach one ppm (one mg) but in none of the experiments mentioned here was lead precipitation noticed at the time of its addition. This might be due to the fact that in the current experiments seawater was filtered through a 0.22-μ porosity membrane filter which should remove all particulate matter; however, in the experiments where precipitation was reported to occur at the one mg level, ordinary unfiltered seawater was probably used.

Table 1. Chlorophyll "a" concentration in *Prorocentrum micans* measured in terms of in vivo fluorescence units

	Days								
	Start	2	4	6	8	10	12	14	16
Control	17/30X	42/30X	65/30X	34/10X	58/10X	41/3X	59/3X	26/1X	35/1X
25 µg	17/30X	36/30X	60/30X	35/10X	60/10X	40/3X	57/3X	29/1X	35/1X
100 µg	17/30X	33/30X	65/30X	34/10X	63/10X	42/3X	65/3X	33/1X	41/1X
500 µg	17/30X	32/30X	57/30X	30/10X	55/10X	41/3X	69/3X	34/1X	41/1X
1 mg	17/30X	31/30X	49/30X	32/10X	51/10X	36/3X	60/3X	31/1X	35/1X

Table 1. Chlorophyll "a" concentration in *Prorocentrum micans* measured in terms of in vivo fluorescence units

	Days								
	Start	2	4	6	8	10	14	18	20
Control	27/30X	52/30X	35/10X	74/10X	41/3X	64/3X	35/1X	52/1X	62/1X
100 µg	27/30X	46/30X	37/10X	70/10X	40/3X	70/3X	36/1X	51/1X	60/1X
500 µg	27/30X	48/30X	34/10X	65/10X	39/3X	70/3X	36/1X	61/1X	69/1X
1 mg	27/30X	47/30X	35/10X	69/10X	40/3X	66/3X	35/1X	56/1X	62/1X
2.5 mg	27/30X	44/30X	29/10X	63/10X	39/3X	71/3X	36/1X	60/1X	67/1X

Table 3. Chlorophyll "a" concentration in *Scrippsiella faeroense* measured in terms of in vivo fluorescence units

	Days										
	Start	1	3	5	7	9	11	13	15	17	19
Control	25/30X	33/30X	52/10X	98/3X	79/1X	57/1X*	72/1X*	96/1X*	91/1X*	[illegible]/1X**	52/1X**
25 µg	25/30X	33/30X	50/10X	51/3X	60/1X	42/1X*	56/1X*	76/1X*	76/1X*	[illegible]/1X*	49/1X**
100 µg	25/30X	29/30X	40/10X	34/3X	32/1X	21/1X*	49/1X*	54/1X*	54/1X*	[illegible]/1X*	71/1X*
500 µg	25/30X	27/30X	46/10X	37/3X	26/1X	16/1X*	36/1X*	47/1X*	53/1X*	61/1X*	63/1X*
1 mg	25/30X	32/30X	44/10X	34/3X	22/1X	13/1X*	29/1X*	37/1X*	36/1X*	41/1X*	40/1X*

*twice diluted **4 times diluted

Table 4. Chlorophyll "a" concentration in *Scrippsiella faeroense* measured in terms of in vivo fluorescence units

	Days								
	Start	1	3	4	6	8	9	11	12
Control	77/30X	53/10X	75/3X	43/1X	40/1X*	28/1X*	71/1X*	75/1X*	82/1X*
25 µg	77/30X	34/10X	80/3X	45/1X	39/1X*	71/1X*	66/1X*	74/1X*	76/1X*
100 µg	77/30X	53/10X	75/3X	40/1X	33/1X*	52/1X*	52/1X*	60/1X*	64/1X*
500 µg	77/30X	54/10X	59/3X	31/1X	24/1X*	36/1X*	39/1X*	47/1X*	56/1X*
1 mg	77/30X	39/10X	47/3X	23/1X	19/1X*	32/1X*	31/1X*	41/1X*	43/1X*

*twice diluted

Riley et al. (1964, 1965) and Bryan (1971) reported adsorption of dissolved matter on already existing particulate matter in the solution. It may therefore be concluded that in filtered seawater lead will not precipitate as readily as in unfiltered seawater. The appearance of precipitates after a few days in cultures containing one mg lead suggests that in addition to particulate matter produced, the cell excretions were mainly responsible for the precipitates. Some further evidence to this effect was also noted. When 2.5 mg lead (equivalent to 3.9952 mg lead nitrate) were added to one liter of a culture medium in which *Prorocentrum* cells had grown for 3 days (concentration of 156 cells/ml) the entire medium turned milky white. The precipitate later settled at the bottom of the flask. Contrariwise, when the same amount was added to a freshly membrane-filtered seawater, with no particulate matter of any kind, such milkiness did not appear in the medium.

In conclusion, there are a number of processes leading to removal of dissolved lead from the medium, such as precipitation with phosphates and extracellular products, and adsorption on particulate matter. At the same time, there were certainly indications that lead was taken up by the cells, otherwise inhibition in growth and uptake of radioactive carbon should not have occurred. A number of workers reported the uptake and accumulation of lead by phytoplankton in nature (Knauer and Martin, 1973; Abdullah and Royle, 1974) and in experimental cultures (Riley and Roth, 1971; Lewin, 1974).

Compared with cell numbers and chlorophyll "a" concentration, the rate of uptake of radioactive carbon by both species decreased gradually with increase in concentration of lead (Fig. 6-8). A 50% reduction in uptake of radioactive carbon was noted on the tenth day at one mg level compared with the control in *Prorocentrum micans* (Fig. 6 and 7). The rate of uptake at 2.5 mg lead was unexpected, however, as it was higher than at one mg; this may be attributed to inadvertent experimental error. This increased carbon uptake at higher levels is not significant, as Malanchuk and Gruendling (1973) observed the uptake of radioactive carbon by *Ochromonas malhamensis* to increase with increasing lead concentrations. The rate of uptake of radioactive carbon by *Scrippsiella* (Fig. 8) decreased more rapidly with increasing lead concentrations compared with *Prorocentrum*.

When the rate of uptake of radioactive carbon was compared with cell numbers counted simultaneously it becomes apparent that both were affected differently. This means that the decrease in the uptake of radioactive carbon by cells was not due to decrease in numbers but rather to a direct effect of lead. If this is true, then the question arises as to whether lead was able to penetrate the cell membrane and reach the chloroplasts. Motto et al. (1970) reported absorption of dissolved lead by bean plant roots. However, the possibility that lead deposited on the cell membrane causes physical blockage of the movement of materials across it is also plausible (Malanchuk and Gruendling, 1973).

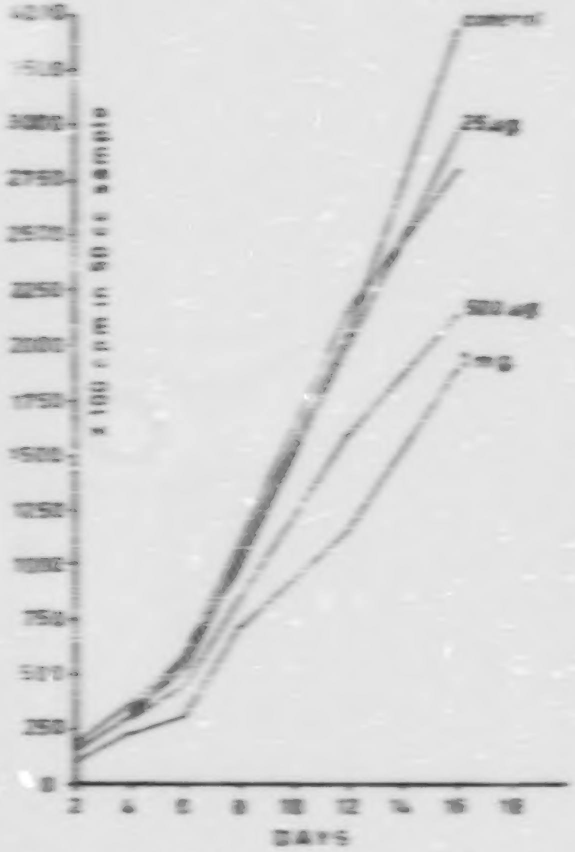

Figure 6. Effect of lead on rate of of uptake of radioactive carbon by *Prorocentrum micans*

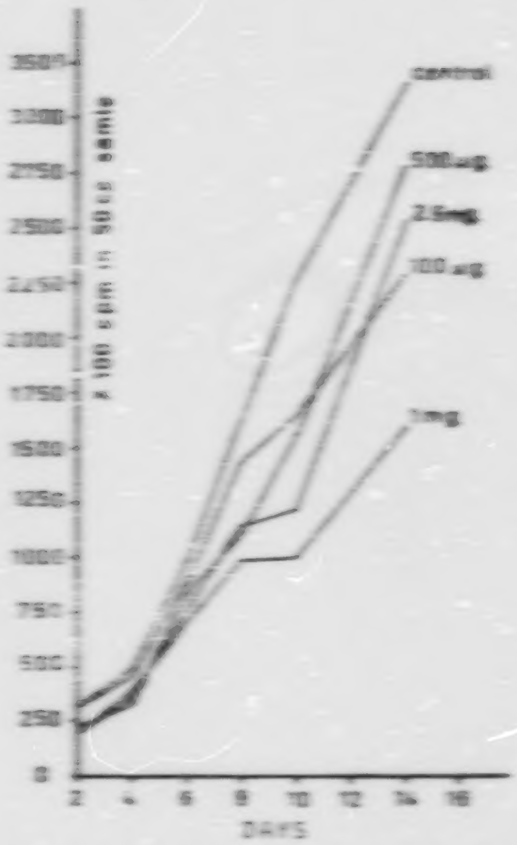

Figure 7. Effect of lead on rate of uptake of radioactive carbon by *Prorocentrum micans*

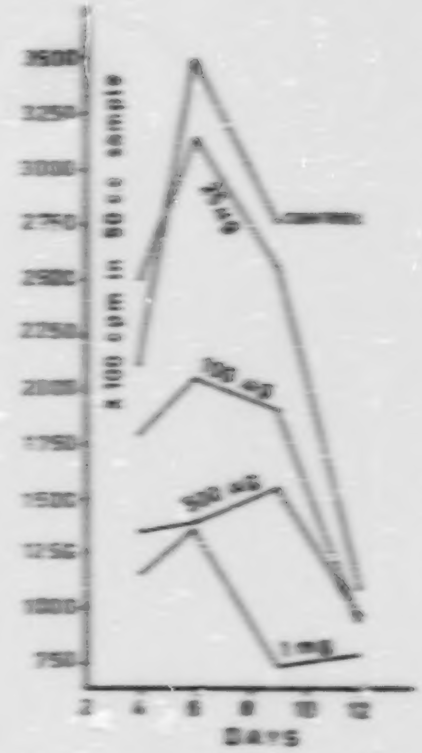

Figure 8. Effect of lead on rate of uptake of radioactive carbon by *Scrippsiella faroens*

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BIOASSAYS AS INDICATORS OF POLLUTION EFFECTS

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INTRODUCTION

The objective of marine bioassay usually is to determine a pollutant's (a) concentration harmful to organisms, (b) persistence and degradability, (c) rate of accumulation and loss in organisms consumed by other organisms, and (d) mode of action on organisms. These data are used to establish water quality standards. Although it is not practical to study all species that may be affected by a pollutant, a variety of marine or estuarine species may be tested to estimate which taxonomic groups are most sensitive. Findings may result in a recommendation that a particular pollutant not be allowed to exceed certain concentrations for a particular period, and restriction of use and disposal may result. When it is shown that monitoring of concentrations in water or organisms is not adequate to indicate effects, additional standards may be recommended, such as in situ measurement of persistent and cumulative enzyme inhibition in organisms caused by metabolites that are not chemically measurable in organisms.

The bioassays used at the U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, Florida, may be regarded as three interrelated types: macroscopic, microscopic, and metabolic (Fig. 1). I will briefly review some of the bioassays and results as examples of their variety and applications.

EXAMPLES OF BIOASSAYS WITH MACROSCOPIC ORGANISMS

Mangrove. Seedlings of the mangrove (*Rhizophora mangle*) have been tested for response to herbicides, insecticides and polychlorinated biphenyls (PCBs). Seedlings were exposed in three stages: (a) no leaves extended, (b) one pair of leaves extended, and (c) two leaves extended. The plants had been planted in plastic boxes and maintained under estuarine conditions. In one bioassay, soil was treated with the herbicide Tordon 101 (a mixture of about 40% 2,4-D and 14% picloram). Application of 11.2 kg/ha killed all plants within 40 days. Plants treated before leaf extension with 11.2 and 112 kg/ha accumulated up to 0.81 and 4.10 mg 2,4-D/kg in hypocotyl, respectively, after 30 days; accumulation of picolinic acid was 0.14 and 0.58 mg/kg. Plants treated before leaf extension with 1.12 kg/ha showed retarded growth. Seedlings treated during the single pair leaf stage with 11.2 kg/ha also accumulated 2,4-D and picolinic acid in hypocotyl, stem and leaves after 30 days but concentrations in hypocotyl were lower than in the stage with no leaves (Walsh et al., 1973). Mangrove seedlings treated with the organochlorine insecticides dieldrin, methoxychlor, Mirex, and the PCB, Aroclor 1254, also translocated them from soil to various plant parts. Dieldrin was detected in hypocotyl and leaves of seedlings at application rates of 0.6 kg/ha and above, while methoxychlor was detected in hypocotyl after application of 0.28 kg/ha and above. Aroclor 1254 was detected in hypocotyl and leaves after application of 0.56 kg/ha and above, and Mirex was detected in roots, hypocotyl, stems, and leaves only at the high rate of 11.2 kg/ha (Walsh et al., 1974).

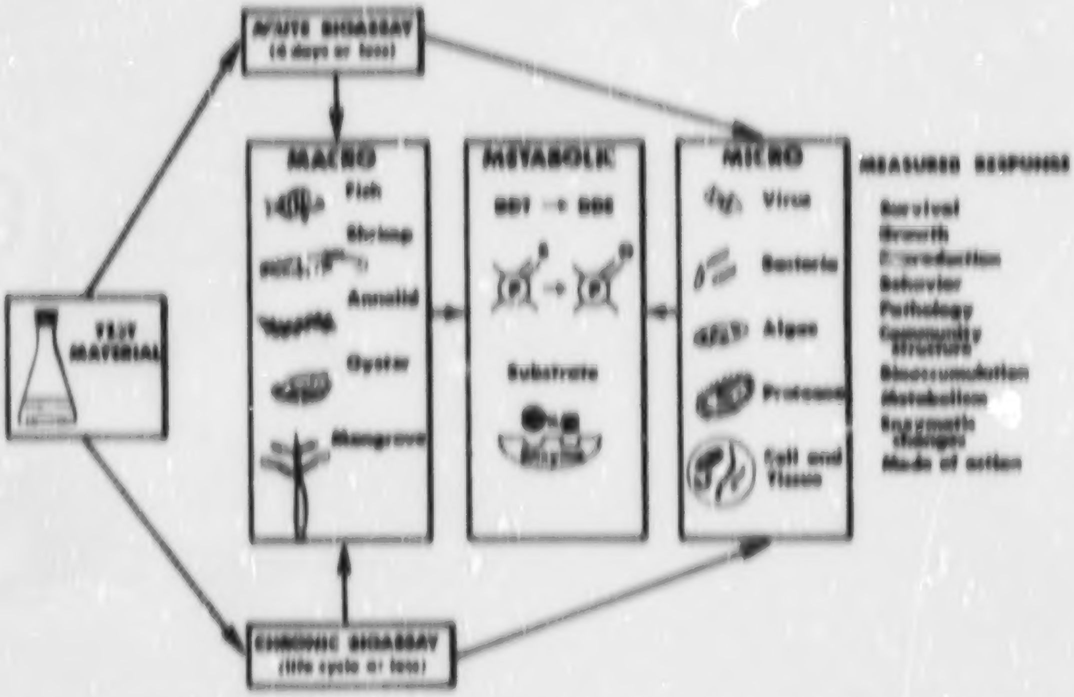
ACUTE BIOASSAY
(4 days or less)
TEST MATERIAL
MACRO
Fish
Shrimp
Annelid
Oyster
Mangrove
METABOLIC
DDT → DDE
Substrate
Enzyme
MICRO
Virus
Bacteria
Algae
Protozoa
Cell and Tissue
MEASURED RESPONSE
Survival
Growth
Reproduction
Behavior
Pathology
Community structure
Bioaccumulation
Metabolism
Enzymatic changes
Mode of action
CHRONIC BIOASSAY
(life cycle or less)

Figure 1. Bioassays used as indicators of effects of marine pollution.

Short-Term and Life-Stage Bioassays of Animals. Short-term bioassays (96 hr) of acute toxicity have been made with such insecticides as dieldrin, endrin, heptachlor, heptachlor epoxide, chlordane and methoxychlor with oysters, fish, and shrimp as bioassay animals (Parrish et al., 1973; Schimmel et al., 1974; Bahner and Nimmo, 1975; Parrish et al., 1975; Schimmel et al., 1976). Shrimp (*Penaeus duorarum*) were extremely sensitive to most compounds, with the 96-hr LC_{50} being less than 1 μg/liter (as low as 0.03 μg/liter for heptachlor) with compounds tested except methoxychlor (LC_{50}, 1.4 μg/liter). Bioassays of sensitivity of postlarval grass shrimp (*Palaemonetes pugio*), and embryos and fry of the fishes sheepshead minnow (*Cyprinodon variegatus*), longnose killifish (*Fundulus similis*), mummychog (*F. heteroclitus*), spot (*Leiostomus xanthurus*), silversides (*Menidia menidia*), and striped bass (*Morone saxatilis*) have been carried out because adults may not represent the most sensitive lifestage (Hansen et al., 1973; Schimmel et al., 1974; Middaugh et al., 1975; Parrish et al., 1975; Schimmel et al., 1976). For example, Hansen et al. (1973) showed, in tests where adult sheepshead minnows were exposed to 0.1-10.0 μg Aroclor 1254/liter for 4 weeks, fry produced by fish exposed to 0.14 μg/liter or more had greater mortality than fry from control fish, even though parent fish survived as well as controls. Fry that died came from eggs that usually contained 7 µg Aroclor 1254/liter or more. Adults accumulated up to 30,000 times the amount of Aroclor 1254 added to the flowing water aquaria.

Seasonal Outdoor Bioassays of Animals. Possible seasonal differences in effects of Mirex on blue crabs (*Callinectes sapidus*), pink shrimp, grass shrimp, and sheepshead minnows have been studied by exposing animals in three replicate outdoor tanks (2.4 m diam, flowing saltwater depth 30.5 cm) for 28 days during spring, summer, fall and winter. Measured concentrations, added by leaching from a fire ant bait, averaged about 0.04 µg/liter in spring, 0.12 µg/liter in summer, 0.06 µg/liter in fall, and 0.09 µg/liter in winter. Survival of crabs was significantly less than controls (Chi-square tests) in summer and fall but a pronounced difference did not exist (survival was 72% of control). In contrast, 87% or more of control pink shrimp survived in summer, fall and winter, but survival of exposed groups was 0, 19, and 49% for each season, respectively. Grass shrimp showed only 10 and 59% survival in summer and fall, respectively, compared with 75 and 98% survival of control groups. Sheepshead minnows suffered no significant mortalities greater than that of the controls. Earliest deaths occurred in shrimp in 3 days and blue crabs in 6 days. Greatest mortalities were in summer with increased temperature and Mirex concentration. Concentrations in animals and sand were greater than water concentrations at the end of 28 days: sheepshead minnows 40,800 X, blue crabs 2,300 X, pink shrimp 10,000 X, grass shrimp 10,800 X, and sand substrate was 770 X (Tagatz et al., 1975).

Animal Community Composition. Hansen (1974) showed that the community structure developing from planktonic larvae in flowing seawater entering aquaria containing sand substrate may be altered by minute amounts of Aroclor 1254 (1-10 µg/liter). Although members of 9 phyla (Annelida, Arthropoda, Brachiopoda, Chordata, Coelenterata, Echinodermata, Ectoprocta, Mollusca, and Nemertea) were present after 4 months in 10 control aquaria, only Annelida, Arthropoda, and Mollusca were present in all control aquaria. However, 7 control aquaria contained chordates (primarily the tunicate *Molgula manhattensis*). In aquaria receiving 1-10 µg/liter for 4 months, arthropods decreased and the number of tunicates increased; over 75% of animals were tunicates in 10 µg/liter. Numbers of phyla, species, and individuals (especially amphipods, bryozoans, crabs and molluscs) decreased from exposure.

EXAMPLES OF BIOASSAYS INVOLVING MICROSCOPIC ORGANISMS

Pathogens. Interaction between chemical pollutants and natural pathogens have been studied. For example, enzootic levels of virus in pink shrimp may be altered by exposure to Aroclor 1254, and Mirex (Couch and Nimmo, 1974). Shrimp exposed to 3 µg/liter for 30-50 days accumulated up to 500 mg/kg in their hepatopancreas. About 50% of shrimp were killed after 30 days exposure and about 60% of the exposed shrimp were infected with virus (*Baculovirus penaei*) in epithelial cell nuclei of the hepatopancreas; control shrimp were free of infection. Shrimp exposed to 0.01-0.23 µg Mirex/liter for 30 days had 81% mortality and 38% had patent virus infection compared with 9% mortality and 6.6% patent virus infection in control shrimp. Apparent enhancement of prevalence of virus by chemical pollutant stress occurred.

Bacteria and Yeasts. Microbes are important in the marine environment in cycling nutrients, as food for some other organisms, and as degraders of organic material. They are tested in the laboratory for their growth response and capacity to degrade pollutants. For example, bacterial and yeast isolates from estuarine water and sediments were examined for growth after 24-48 hr incubation on marine agar media to which discs containing 0.1, 0.25 and 0.5 mg of Aroclor 1242 or Aroclor 1016 were applied. Sensitivity was defined as the zone of inhibition (lack of growth) surrounding the discs. Yeasts were not sensitive to the Aroclors but 28 of 108 bacterial isolates were inhibited. Among the most sensitive bacteria were *Flavobacterium* sp., *Pseudomonas* sp., and *Bacillus* sp. The majority of the sensitive strains produced amylase (75%) and gelatinase (89%). Four estuarine species in liquid media (50-100 ml) containing 10 μg of Aroclor 1242 were measured for growth by absorbance spectrometry; two species were completely inhibited in 18 hr. The gram-positive isolate of *Bacillus* sp. and a *Pseudomonas* sp. were inhibited in liquid media containing 1 μg Aroclor 1242 within 16 hr (Bourquin et al., 1975).

Effects of malathion and Mirex on a salt marsh microbial system also have been studied. The system consisted of sifted sand and water in battery jars maintained under estuarine conditions (Bourquin, 1975). The slowly aerated systems were stabilized for one week following which malation was added and at every subsequent 10 days for 30 days at rates of 420 and 4,200 g/ha. Appropriate inoculation or plating on various media at the end of the treatment indicated no differences in total heterotrophic activity between control and treated microcosms. Numbers of malathion-metabolizing bacteria increased slightly in treated systems and malathion co-metabolizing bacteria, i.e., those metabolizing malathion in presence of 2% peptone, increased by an average of more than 20% compared with controls. Treatment of similar microbial laboratory systems with 100 and 1,000 μg Mirex/liter produced no differences among control and treated system based on numbers of heterotrophic bacteria. Some decrease occurred in bacterial growth upon transfer to nutrient media containing 10 μg Mirex/ml after initial treatment of the system. The growth inhibition was not observed after initial treatment. No Mirex-degrading bacteria were selected by replica-plating procedure, and no stimulatory or inhibitory effect, other than the growth inhibition in the initial treatment, was observed.

Algae. Marine unicellular algae have been tested for changes in oxygen evolution and decreased growth response upon exposure to several classes of herbicides (Walsh, 1972). Herbicides tested included (a) the triazines ametryne, atrazine, simazine, and prometone; (b) the ureas diuron, neburon, monuron, and fenuron; (c) the phenoxy acetic acids 2,4-D and 2,4,5-T; (d) the propionic acids silvex and dalapon; (e) the benzoic acid chloramben; (f) the nitril dichlobenil; (g) the phthalic endothal; (h) the dipyridyliums paraquat and diquat; and (i) the toluidene trifluralin. The chlorophytes *Chlorococcum* sp. and *Dunaliella tertiolecta* and the chrysophytes *Isochrysis galbana* and *Phaeodactylum tricornutum* were most sensitive to some formulations of ametryne, atrazine, diuron, neburon, and monuron. Oxygen evolution decreased by 50% after 90 min exposure and growth measured during the logarithmic phase decreased by 50% after exposure for 10 days to concentrations of 10-300 μg herbicide/liter medium. Herbicides other than the triazines and ureas required more than 1,500-5,000,000 μg/liter to produce a 50% decrease in oxygen evolution and growth.

Differential response of 18 marine unicellular algae phytoplankters comprising 4 families was studied by measuring oxygen evolution after incubation with herbicide (Hollister and Walsh, 1973). In this bioassay, the EC_{50} was defined as the concentration of neburon, diuron, atrazine or ametryne that reduced oxygen evolution by 50% after 60 min exposure. Wide variation in response among individual species of the families, Chlorophyceae, Bacillariophyceae, and Chrysophyceae was found, with EC_{50} values ranging from 10-400 μg/liter. Maximal variation was in the Bacillariophyceae, about 12-fold difference between the minimal and maximal EC_{50}.

Protozoa. The protozoan *Tetrahymena pyriformis* has been used to indicate possible sensitivity of ciliates (the most numerous animals in the estuarine benthos) to pollutants and their capacity to accumulate pollutants (Cooley et al., 1972, 1973). Mirex reduced growth by 33% at 0.9 μg/liter during the exponential growth phase in media in culture tubes measured by spectrophotometric absorbance. Population density was reduced by 12% in 96 hr with 193 times as much Mirex in cells than that added to the media. The species was also sensitive to Aroclor 1254, in that growth rate was reduced 8% and population density in 96 hr at one μg/liter, but cell concentration ranged to only 60 times that added to media. The PCBs Aroclor 1248 and Aroclor 1260 were much less toxic, requiring 1,000 μg/liter medium to produce significant reduction in growth and population density. However, concentration factors ranged to 48 for Aroclor 1248 and 79 for Aroclor 1260.

METABOLIC BIOASSAY

Enzyme Inhibition. The mode of action of organophosphate and carbamate pesticides in animal poisoning is believed to be disruption of nerve impulse transmission at nerve cell junctions by inhibition of the enzyme acetylcholinesterase, the latter which modulates amounts of the neurotransmitter acetylcholine (Corbett, 1974). Bioassay experiments have been designed to interpret inhibition of acetylcholinesterase in brains of fish for use in studies of environmental effects of these pollutants (Coppage, 1972, 1975; Coppage et al., 1975). It has been shown that a relatively constant level of inhibition (70% or more) is critical during acute poisoning, i.e., a level at and below which deaths are likely to occur in exposed populations. This direct measure of mechanism of injury of fishes in the environment overcomes the problems of interpretation where complete history of residues is lacking. The inhibition is cumulative and persistent because of relatively irreversible phosphorylation or carbamylation of the enzyme, but the enzyme-bound metabolites of the pesticides are not measurable in environmental samples. Therefore, present, past, and cumulative effects can be indicated by measuring enzyme activity, but not solely by analytical chemical analyses of environmental residues.

The types of bioassays reviewed are a necessary part of determining water quality under Federal laws. The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, Section 304(a), provide that bioassay data on effects of pesticides and other pollutants on aquatic organisms be obtained for developing water quality criteria. The Federal Insecticide, Fungicide, and Rodenticide Act, FIFRA (as amended), provides that data on hazards of pesticides to non-target organisms include acute toxicity to fish and may require acute toxicity testing of invertebrates, aquatic organisms life cycle studies, and simulated field testing. The

Administrator of the Environmental Protection Agency may issue notice of intent to cancel registration of a pesticide if it appears to the Administrator that it generally causes unreasonable adverse effects on the environment as indicated under "criteria for risk" of FIFRA which include bioassays of aquatic organisms.

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CHEMISTRY AND CIRCULATION MODELING IN THE LAKE OF TUNIS: A MARINE LAGOON

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INTRODUCTION

The EPA-sponsored project on marine pollution in Lake Tunis is run in conjunction with the Institute National Scientifique et Technique d'Oceanographie et de Pêche (INSTOP). Lake Tunis is a hypersaline lagoon on the north coast of Africa in Tunisia, outside of the city of Tunis. This lagoon, once in direct contact with the Mediterranean Sea as part of the Gulf of Tunis (Stirn, 1966), was separated from the Gulf of Tunis by the formation of a land spit. At present the lagoon is split by a navigational canal leading to the city of Tunis, dividing it into two parts referred to as the north and south lakes or lagoons. These separate parts, which connect with the Gulf of Tunis via some smaller canals, are highly polluted, the south lagoon being predominantly affected by an industrial complex and the north lagoon by the sewage of the city of Tunis and other surrounding communities (Fig. 1). Much of the work in this project has concentrated on understanding the nature of eutrophication of the north lake where the Tunisian government plans to begin a sewage diversion project as a first step in restoration of the lake. Additional information on Lake Tunis can be obtained from a number of sources (Stirn, 1966; Crouset, 1973; Bjork, 1972; Anonymous, 1975).

Briefly, the total lagoon area is 45 km^2 with an average depth of about one meter. The shallowness of the lagoon is produced primarily by rapid sedimentation as well as by the growth of large areas of worm reefs. In the summer when there is no rain, high temperatures and the winds are weak, resulting in an average salinity much higher than that of the Mediterranean (Fig. 2). Biological production in the lagoon is rapid, and under low wind conditions the surface of the north lagoon may be as much as one-third covered by a leafy algae, *Ulva*. In August or early September, the combination of decreased oxygen transfer, due to low winds and algal cover, and high BOD produces an anaerobic condition in the north lagoon. This results in a general deterioration frequently characterized by the "blooming" of a chromic sulfide bacteria, referred to locally as a red tide. In the winter, a rainy season, strong winds and lower temperatures combine to recharge the lagoon, reducing the average salinity below that of the Mediterranean, and averting anaerobiosis. Lastly, the north lagoon is used year round as a heat sink for two large power stations.

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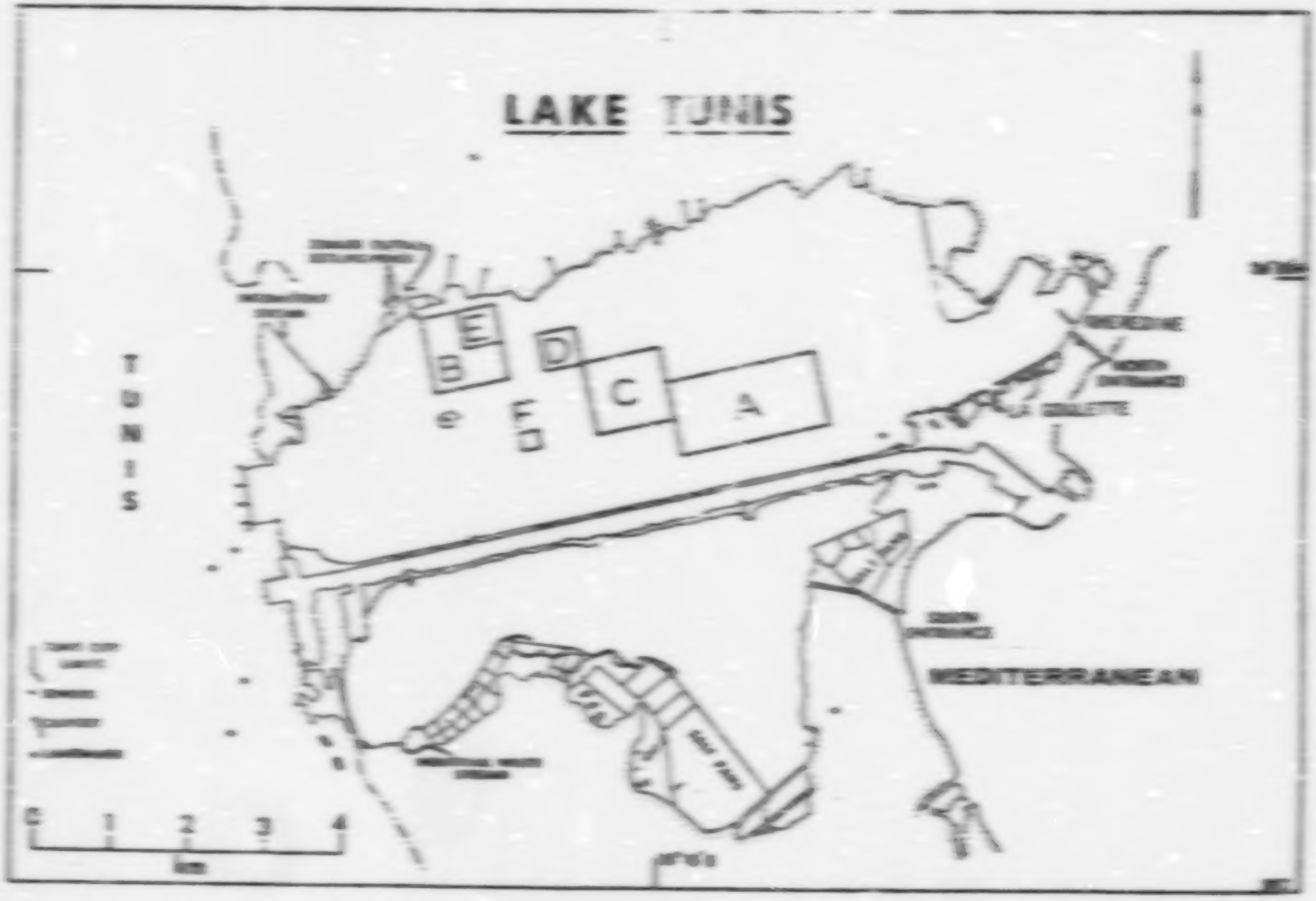
LAKE TUNIS
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TUNIS
NORTH ENTRANCE
LA GOULETTE
SOUTH ENTRANCE
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Figure 1. Map of Lake Tunis. A = sand; C,D,F = reefs; B,E = sewage.

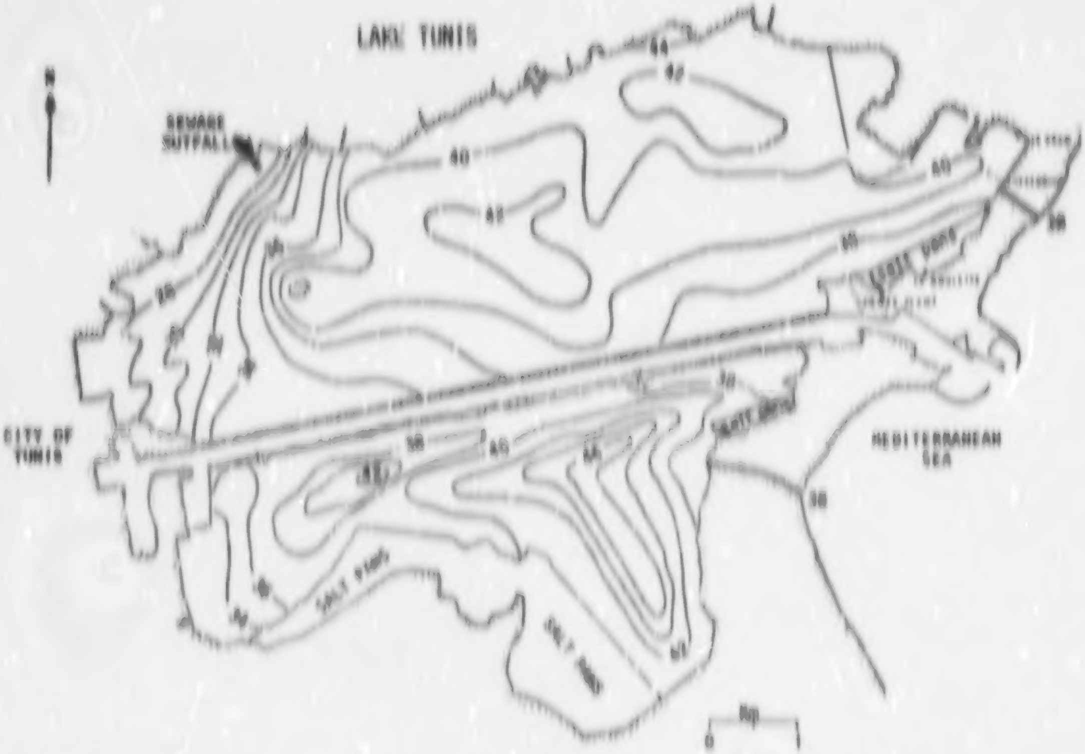


Figure 2. Salinity (ppt) of Lake Tunis, summer 1973 (contour interval = 2 ppt). Source: Harbridge et al. (1976a)

The EPA project to model the eutrophication of Lake Tunis is directed by T. E. Maloney of the EPA and F. Ktari of INSTOP. The project is subdivided into a geological program headed by O. H. Pilkey of Duke University; a biological program overseen by Mme. Ktari, with the principal scientist being Mohedine Belkir of INSTOP; a water chemistry study under the supervision of R. W. Baier, of the Duke University Marine Laboratory, part of which involves a heavy metal study by P. J. Whaling, also of the Duke Marine Laboratory; and a hydrological program under the supervision of R. E. Johnson of the University of Virginia. The data gathering and analysis have jointly involved Tunisian and American technicians who have been working at INSTOP under the supervision of Mme. Ktari. In the present paper we describe the work underway on the chemical studies and modeling of the nutrient transports in the north lagoon. Other aspects of the overall program have been reported elsewhere (Harbridge et al., 1976a,b) or are in preparation.

LAKE CIRCULATION

Our program for measuring the physical properties of the north lagoon, in conjunction with previous work on Lake Tunis (Stirn, 1966; Crousset, 1973; Bjork, 1972; Anonymous, 1975), has provided a data base which can be used to determine the important physical parameters for a mathematical model of the circulation under varying wind and tidal conditions.

Such a model, coupled with the nutrient transport equations presented here, can be used to determine expected nutrient levels across the lagoon when any of the proposed physical changes are carried out. The average water volume of the north lagoon is about 27×10^6 m^3, which is "refreshed" in the summer, when there are no rains, by three small canals (Fig. 1), which connect with the ship canal and exchange, when there are no winds, a total water volume of about 1.5×10^6 m^3 per day. The power stations adjacent to the salt pans pump an additional 1×10^6 m^3 per day from the canal to the north lagoon. As noted subsequently, the ship canal waters, however, can hardly be considered nutrient-free. The primary source of low-nutrient water is a small canal directly connected to the Gulf of Tunis (Mediterranean) between La Goulette and Kheredine, exchanging, under low wind conditions, about 0.5×10^6 m^3 per day (Fig. 1). The wind has a significant effect, however, on the above exchange rates. The north lagoon receives about 5×10^4 to 8×10^4 m^3 of waste water per day, primarily from the area near the city of Tunis. In the summer the evaporation rate is about 1×10^5 m^3 per day from the north lagoon, and the winds are primarily from the northwest.

Measured vertical profiles of salinity, nutrient concentration and temperature indicate a strong vertical mixing, implying that a two-dimensional model of the circulation would be adequate. Velocity profiles indicate a definite gradient in the horizontal velocity which varies throughout the lagoon. Typical profiles were used when the three-dimensional equations were vertically averaged (Pritchard, 1970; Harlow and Amsden, 1971) to obtain a two-dimensional model. Because of the shallowness and low water velocities, the momentum convection and diffusion terms (Pritchard, 1970) can be neglected. These are the terms primarily affected by the character of the velocity profiles, and, therefore, in the first approximation the vertical gradients do not play a role. Using typical values of velocity and characteristic depths, a momentum diffusion coefficient of the order of 10^3 cm^2/sec is estimated, in which case the momentum diffusion term is significantly smaller than the momentum convection contribution, which in turn is a couple of orders of magnitude smaller than the pressure term in the momentum equations. Because the response time of the lagoon to changes in wind stress is short and the water velocities are small, the coriolis effect is negligible, although we have included it for completeness. Lastly, the horizontal gradients in salinity may be significant in some parts of the lagoon (Fig. 2). Under typical wind conditions this contribution is smaller than pressure gradients produced by the wind stress and, therefore, for the calculations discussed here, we have neglected this contribution to the pressure gradient.

If U and V are the x and y components of the horizontal velocity times the water depth, the x-axis chosen to lie parallel to the ship canal, b the initial water depth, and h the excursions in depth about b, then the vertically averaged continuity equation is:

$$\frac{\partial h}{\partial t} = -\left(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y}\right) - (E - P) \tag{1}$$

where E and P are evaporation and precipitation rates (Pritchard, 1970). The vertically averaged momentum equations are:

$$\frac{\partial U}{\partial t} = -g(h + b)\frac{\partial h}{\partial x} + A_x - B_x + fV \tag{2}$$

and

$$\frac{\partial V}{\partial t} = -g(h + b)\frac{\partial h}{\partial y} + A_y - B_y - fU \tag{3}$$

where g is the acceleration of gravity, $A_{x,y}$ and $B_{x,y}$ are the components of wind and bottom stress on the water body and f is the coriolis parameter ($f = 1.45 \times 10^{-4}\ \mathrm{sec}^{-1}$). In this approximation, the model requires knowing the bathometry of the lake, sources of water, and empirical determinations of wind stress and bottom friction. For instance, assuming that $b \gg h$, $\vec{B} = \vec{U}/\tau$, where $\tau = \tau(b, |\vec{U}|)$ and $\vec{U} = U\hat{x} + V\hat{y}$, then if the magnitude of the water velocity varies slowly across the lake, the vorticity, ζ, can be written in the form

$$\vec{\zeta} = \tau(\nabla \frac{1}{b} \times \vec{A}) \tag{4}$$

as $f \ll 1/\tau$ in the lagoon. Since the vorticity essentially describes the current patterns, it can be seen that the bottom contours and wind direction determine the circulation. Also, τ is the time constant which determines how rapidly the lake comes into equilibrium for a change in the wind stress or tidal levels.

The bottom friction was modeled using the Chezy coefficient (Pritchard, 1970), C_h, so that $\tau = C_h^2(b + h)^2/|\vec{U}|g$ in our notation. For a body of water of average depth 100 cm with an earth floor (Dronkers, 1964), $g/C_h^2 = 0.012$. With this value, the damping of oscillations in the lake is rapid, in agreement with observation. The wind stress was modeled similarly, $\vec{A} = C_w g\, \vec{W}|\vec{W}|$, where $\vec{W}$ is the wind velocity. For a constant wind velocity, the computed slope of the water surface in equilibrium was found to depend only on the wind stress. The value $C_w g = 2 \times 10^{-6}$ was employed based on measurements of lake seiche under various wind conditions (Anonymous, 1975). The magnitude of the calculated water velocities in the lagoon under a given wind stress were fairly sensitive to the choice of the coefficient g/C_h^2. Varying the value of this quantity from 0.006 to 0.016, we found that the original estimate, 0.012, gave velocity magnitudes throughout the lagoon that were in reasonable agreement with the measured current fields, except when large patches of floating *Ulva* were found in shallow areas of the lagoon during the summer.

Difference equations were constructed for Eqs. 1-3. Values of h at each new time step were solved for iteratively, using over relaxation, from values of h, U and V at the previous time step. New values of U and V were then obtained from time centered values of h. The transport of water through the small canals into and out of the lake was treated hydrostatically. That is, the volume transport through each weir, Q, is assumed to be given by

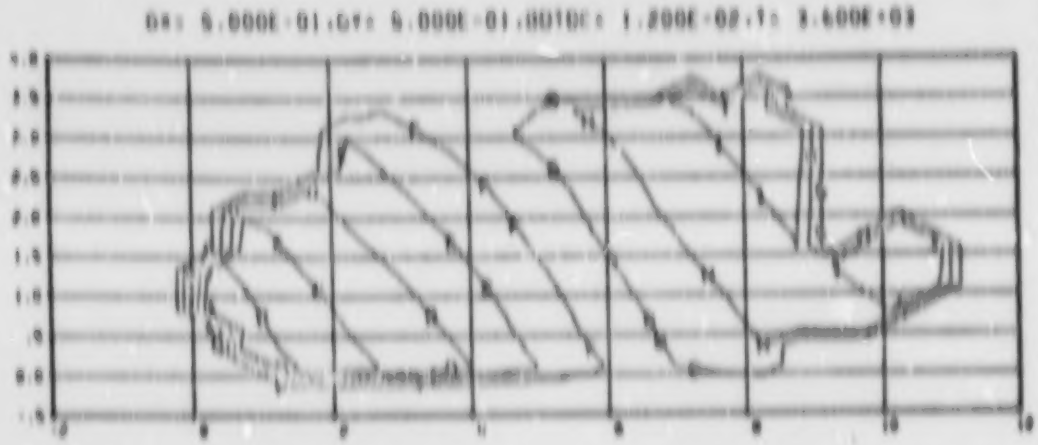
$$Q = C\sqrt{2\, g\, \Delta h}$$

where Δh is the tidal height difference across the weir and a value for C was chosen for each weir to reproduce the measured volume transports discussed earlier. Constant inputs were used for waste water near the city of Tunis and for the water pumped in from the power station. The depth field used is described by Stirn (1966). These depths are now being checked to account for worm reefs.

Using a grid size of 1/2 km in the x-direction, parallel to the ship canal, and 1/4 km in the y-direction, we numerically integrated the equations to obtain flow descriptions for a number of wind and tidal situations. In Figure 3 a plot of surface deviation under a 6 m/sec wind from the southwest indicates that the slope is fairly uniform across the lake and independent of the bottom topography. In Figure 4 is shown the tidal current field times depth, indicating water transport, for no wind at low tide in the approximately 12-hr tidal cycle using a 30-cm tidal excursion. The scale for the flow vectors is such that the y-distance between two calculation points on the map (crosses) corresponds to a velocity of 5 cm/sec times the average lagoon depth, 100 cm, with the direction of flow away from the grid point. It is clear that the tidal effect is small, particularly on the northern shore of the lagoon. The fact that the weirs are all located along the southern shore of the lake and the tidal current field is weak means that the water exchange through the weirs, discussed earlier, does not provide "refreshment" for the northern shore of the lagoon. To compare to this we have calculated the velocity field for two wind directions, $W_x = 6$ m/sec, $W_y = 0$ and $W_x = 0$, $W_y = -6$ m/sec, also at low tide. These results, shown in Figures 5 and 6, clearly indicate that wind is the dominant influence on this body of water. However, they also show that the bottom contours of the lagoon, although slowly changing everywhere, result in reasonably complex current fields, because of the shallowness of the lagoon. This, of course, implies that physical changes in the bottom topography may produce very different circulation patterns and, therefore, prevailing wind directions may be able to be exploited to a certain extent, in addition to other changes such as widening the small canals, to improve the flushing rate of the lagoon. Under the present conditions the western part of the lake remains extremely turbid, and the southeastern part relatively clear. The above model is being used to test the effect of various suggested physical changes on the nutrient and mass transports in the lagoon.

NUTRIENT DISTRIBUTION

As the primary source of waste water is the city of Tunis, on the west end of the north lagoon, there is a west-to-east dispersion of nutrients. This is indicated by the phosphate isopleths in Figure 7. Similar distributions were measured for ammonia, nitrate and nitrite. To assess the relative concentrations of nutrients, Figure 8 shows a typical set of data taken just north of the small island. The area with very high nutrient levels on the northwest end of the lake is also extremely turbid, with little *Ulva* growth. The largest concentrations of *Ulva* occur in the areas in which the nutrient levels have intermediate, but still large, values. For Figure 7, this would be roughly the area between the 5 and one μg-at/liter isopleths. This is also the region where worm tube reefs are found at present, though coring has indicated their growth in other areas in the past (Harbridge et al., 1976a). The growth of *Ulva* in this area and its accumulation in areas where the water movement is slow (Fig. 5 and 6) further dampens the convective transport and affects the circulation patterns considerably in the summer. This we model by adjusting the damping coefficient. The significant nutrient levels in the ship canal can be seen from Figure 9, and the expected west-to-east dispersion is also evident here. Because of the low water velocities and small exchange rates with the Mediterranean, the residence time for nutrients in the lagoon is large. Preliminary calculations, using the circulation model discussed, indicate residence times for nutrients entering at the sewage outfall of the order of 10 to 30 days, depending on the wind conditions. The current patterns exhibited show movement of low nutrient water along the south shore and in the eastern end of the lagoon. These areas of the lagoon have low turbidity and much lower algae growth rates. Biomass measurements across the lagoon are in progress. Therefore, widening the north entrance, a project just beginning, may have little effect on the overall lagoon eutrophication, as it will primarily result in increased water movements in the low nutrient areas. We have modeled the nutrient and salt transport equations, and computations are in progress using current patterns under typical wind conditions. These calculations will provide a further test of the circulation model.



DX= 5.000E-01,DY= 5.000E-01,DDTDC= 1.200E-02,T= 3.600E+03

IDENTIFICATION	CONTOUR VALUE
A——A——A——A	-4.903
B——B——B——B	-3.973
C——C——C——C	-3.042
D——D——D——D	-2.111
E——E——E——E	-1.181
F——F——F——F	-.250
G——G——G——G	.680
H——H——H——H	1.611
I——I——I——I	2.542
J——J——J——J	3.472

Figure 3. Surface flow deviation in Lake Tunis under a 6 m/sec wind from the southwest

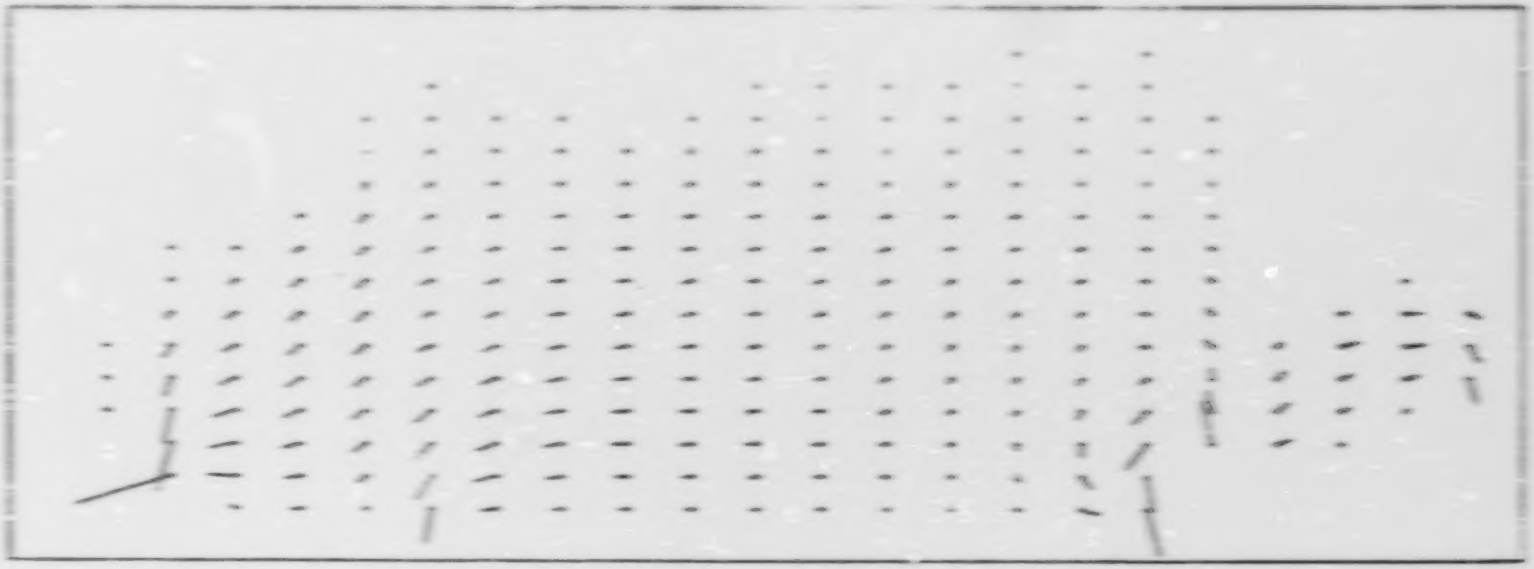


Figure 4. Lake Tunis: tidal current field times depth, indicating water transport, for no wind at low tide

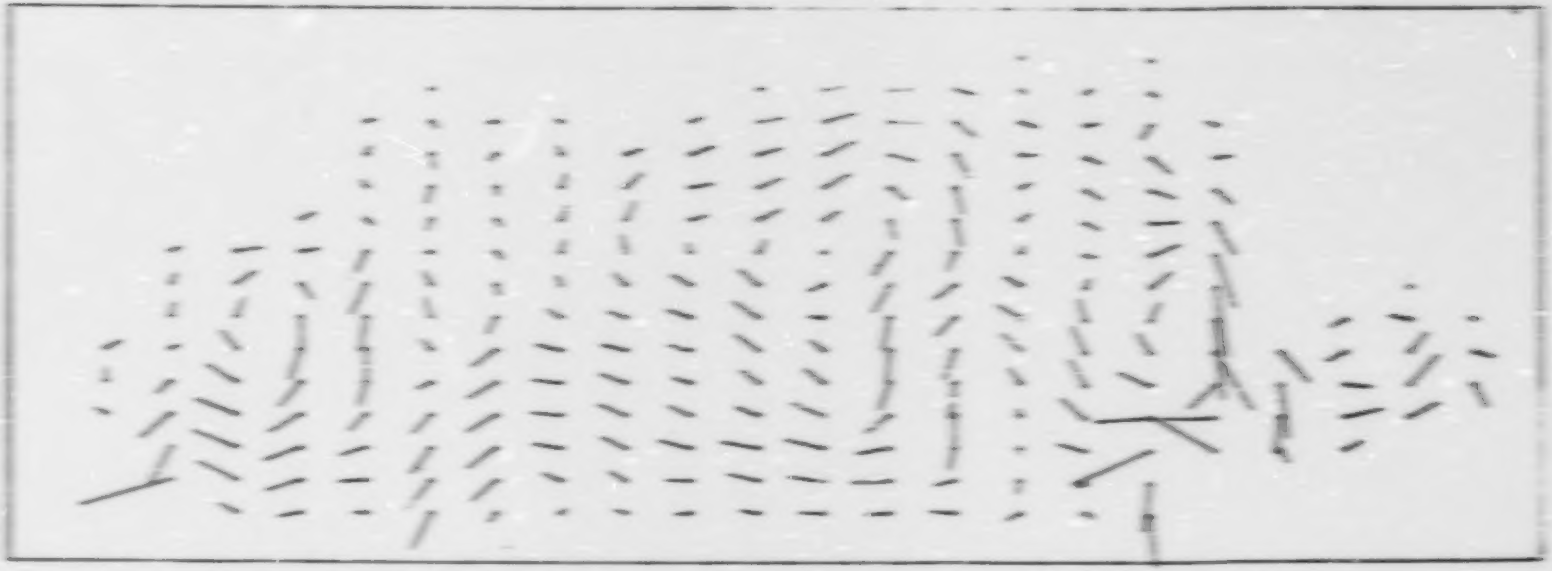


Figure 5. Lake Tunis: calculated velocity field, wind at 6 m/sec, y-direction

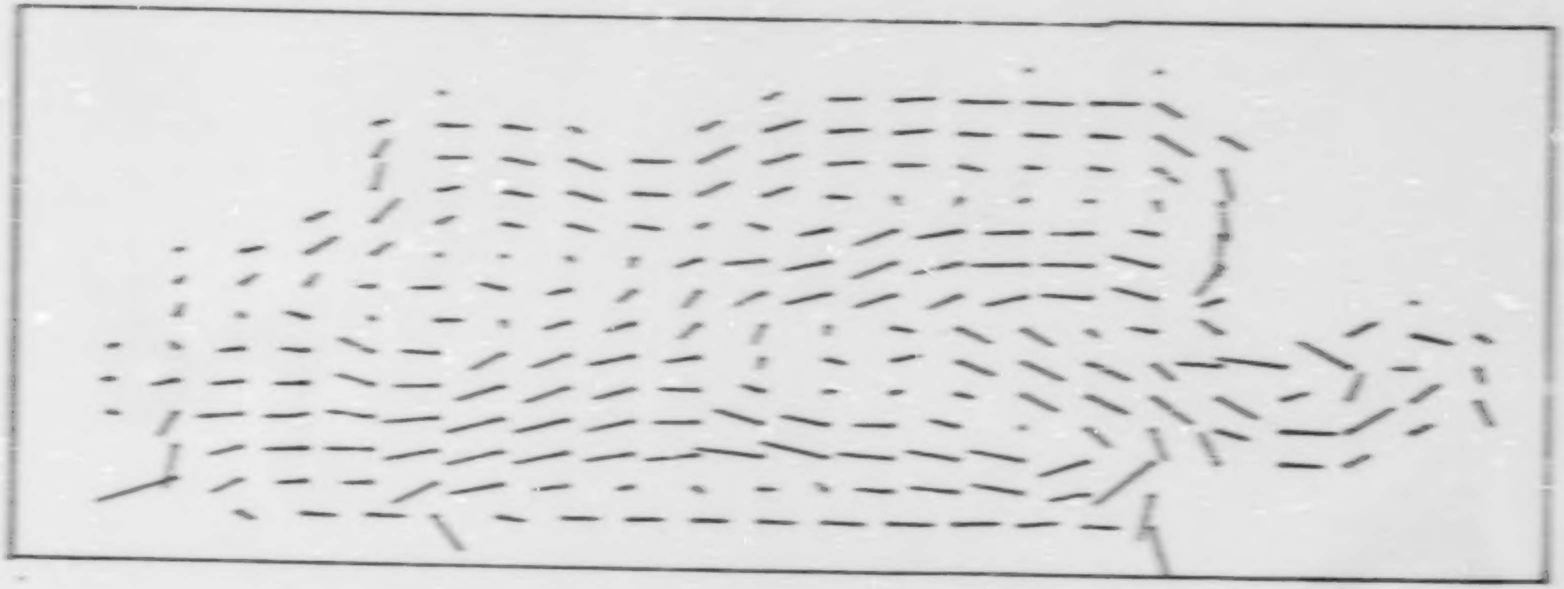


Figure 6. Lake Tunis: calculated velocity field, wind at 6 m/sec, x-direction

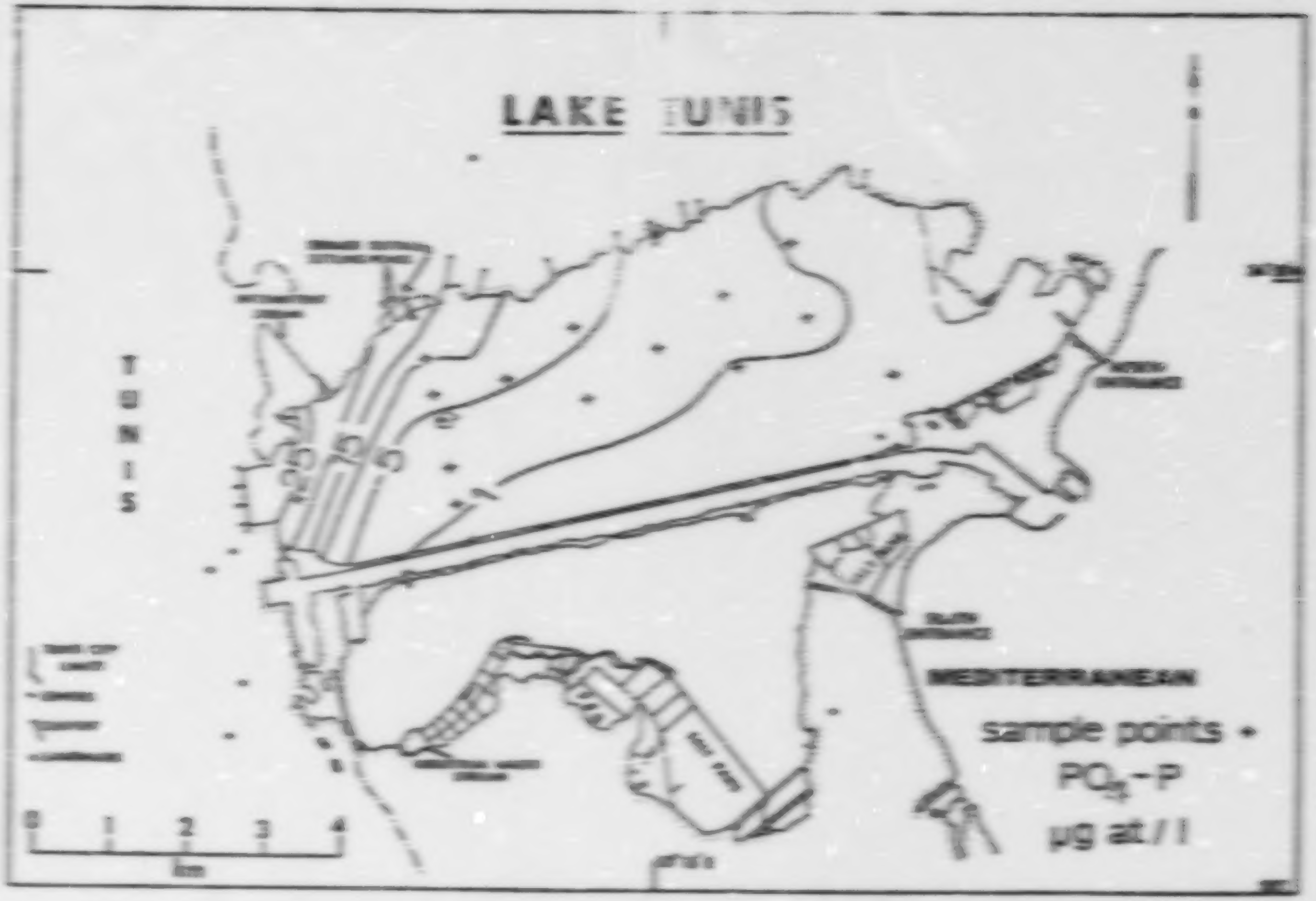

LAKE TUNIS
TUNIS
MEDITERRANEAN
sample points •
PO_4-P
µg at/l
0
1
2
3
4
km

Figure 7. Isopleth map of phosphate distribution in Lake Tunis

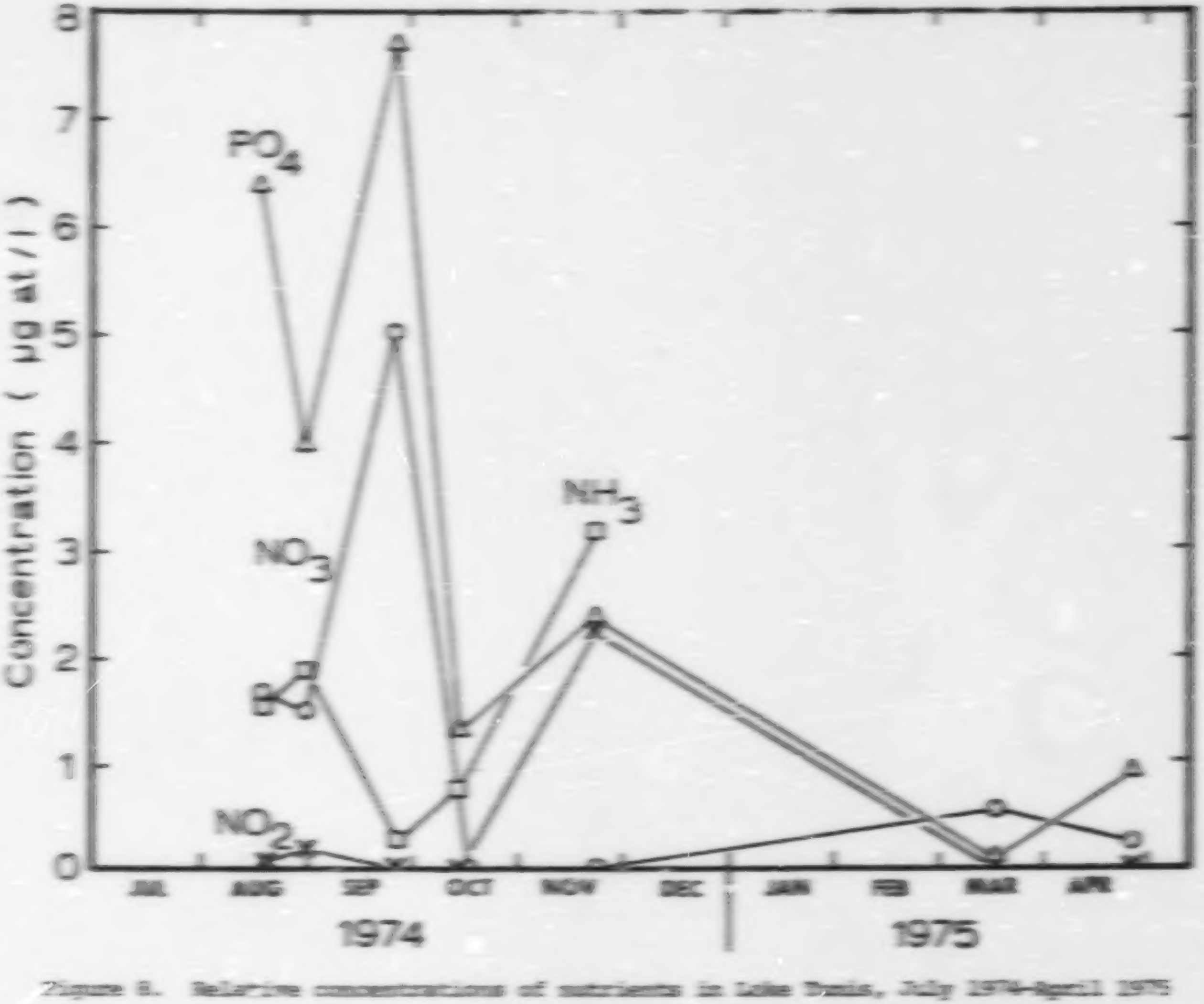


Figure 8. Relative concentrations of nutrients in Lake Tunis, July 1974-April 1975

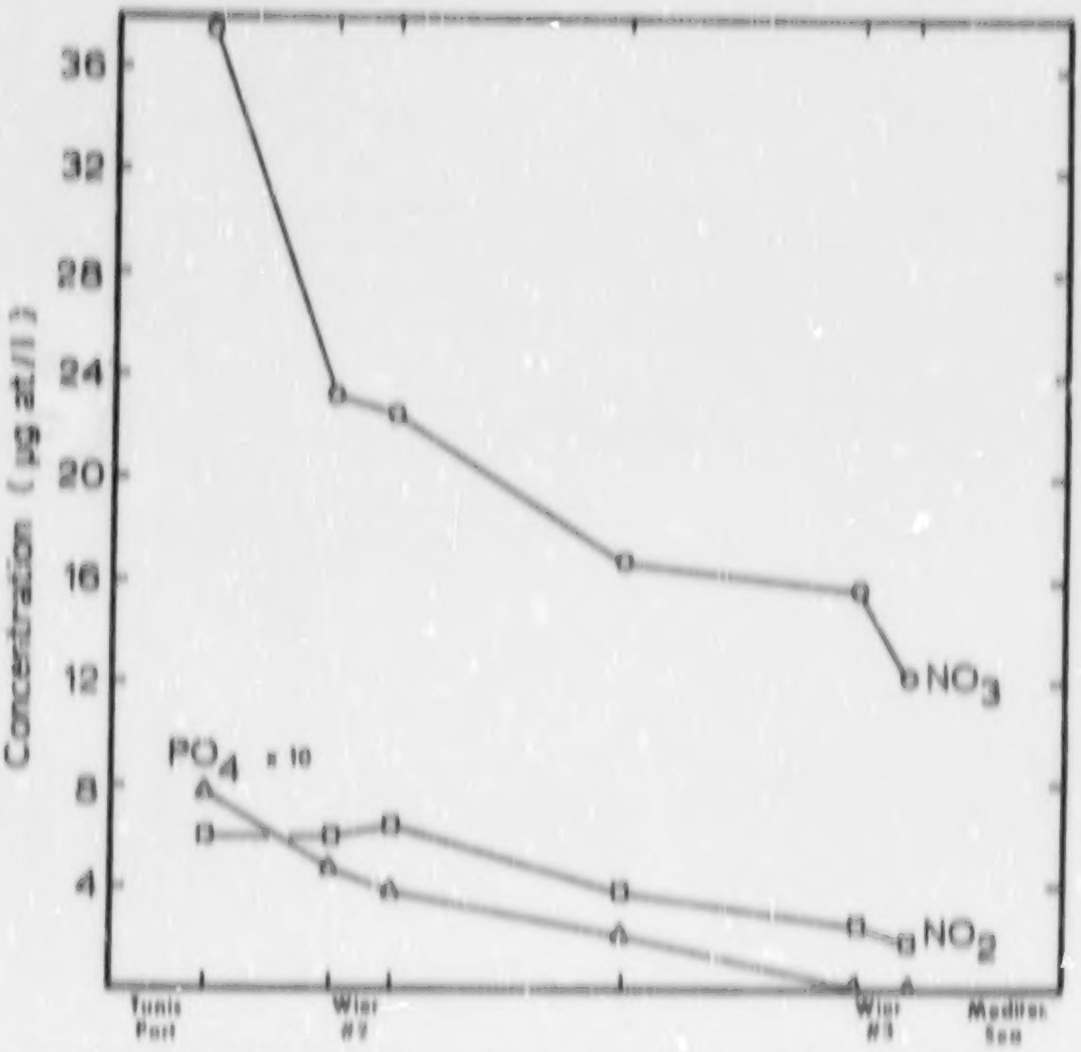


Figure 9. Significant nutrient levels in the ship canal of Lake Tunis, showing west-to-east dispersion

NUTRIENT UPTAKE

One of the major aims of chemical studies in Lake Tunis is to determine nutrient exchange rates with sediment and biota in three distinct lake habitats (sandy bottom, sewer outfall, and dense flora-covered reefs). If chemical analyses of water covering these three habitats can be used to characterize their state of eutrophication, then changes in the state of health of the lake as well as its capacity to remain in good health can be monitored. In addition to providing a criterion for assessing nutrient exchange with biota and sediment, total community uptake rates can be used in conjunction with algal growth rates to determine, by difference, the rate of sediment leaching. By this means, predictions of clean-up rates are possible as Lake Tunis is modified by sewage diversion activities.

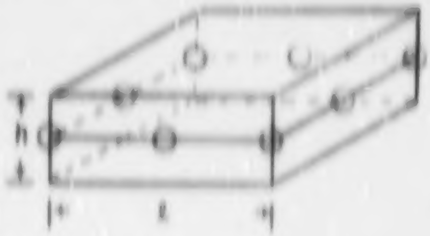
During 1975, 13 self-contained studies were made in North Lake Tunis to estimate O_2, NO_3, and PO_4 uptake rates by the entire biological community along with sediments. These chemical studies were designed to provide data over 9-point grids from which diffusion, advection, and local transports are calculated. By difference the net nutrient uptake from (or input to) the water is obtained. As expected there was considerable time variation in the current field; therefore, statistical evaluation was necessary.

Water analyses were conducted using procedures described by Strickland and Parsons (1972). Replicate chemical analyses fell within the range of precision reported by these workers, but estimates of precision for current measurements could not be obtained. Manufacturer's calibration of a rotary flowmeter (General Oceanics, Inc. Model 2030) was employed throughout the study. Flows within the northern lagoon of Lake Tunis were too low for the calibrated range of the rotary meter, so these current measurements were obtained by extrapolating from the lower portion of the General Oceanics curve. Additional confirmation of the flow structure was obtained with floats driven by water impinging on a high-area vane in the shape of a cross suspended various distances from the float by a thin metal rod. The floats were visible from the surface and could be tracked to obtain speed and direction of water movement at three distinct depths.

Study areas were selected to represent sandy, polluted, and foliated habitats in the north Lake (Fig. 1). Because of the random current field brought about by rapid changes in wind vectors, the size of the grids were decreased from 2 km^2 to 0.06 km^2 during the year.

The rationale for integrating fluxes over the grid is shown in Figure 10. Analysis of the data showed that greater statistical differences between the uptake rates for the various habitats was achieved by averaging the nine currents (i.e., assuming a completely uniform current field) than by using the individual current vectors. All diffusive fluxes were based on an assumed eddy diffusivity, K, between 10^3 and 10^5 cm^2/sec, which covers the range between a value giving a negligible diffuse transport and one that is typical of open ocean estimates (Neuman and Pierson, 1966). The upper value was found to be reasonable based on preliminary dye experiments in which horizontal estimates for K were obtained. No significant differences in results of uptake calculations were apparent when the weighting for the integration routine was changed (Simpson's vs Trapezoidal) or when an "eyeball" estimate of the current field was used to replace the calculated resultant of the individual current measurements. On two dates (25 and 26 September 1975) a total of six missing items of data was estimated by extrapolating from their three closest neighbors in the grid, making it possible to balance the ANOV design.

Although this method of measuring nutrient uptake rates is hampered by considerable noise from a shallow, wind-driven lake, an understanding is gained of total nutrient exchange with the water by biota and sediment. This information cannot be obtained by measuring growth rates for individual algae. Statistical analyses of community uptake rates as measured by the flux budgets over all grids show in most cases greater than 70% confidence of being able to distinguish between the three types of habitats (Table 1). Average concentrations and nitrate to phosphate ratios (Table 2) indicate algal growth to be nitrate limiting, in accord with findings during 1974, but the unknown role played by ammonia has not yet been included for study in this investigation. A large ammonia input can originate from the sewage effluent at the Cherguia treatment plant on the northwest end of the North Tunis lagoon, and presumably animals in the worm tube reefs excrete large amounts of ammonia and provide for significant recycling between plants and animals. Processes for microbial reduction of nitrate in the sediment to form ammonia and nitrite are also known (Terry and Nelson, 1975).



ASSUME CONSTANT DEPTH AND AVERAGE OVER THE VOLUME

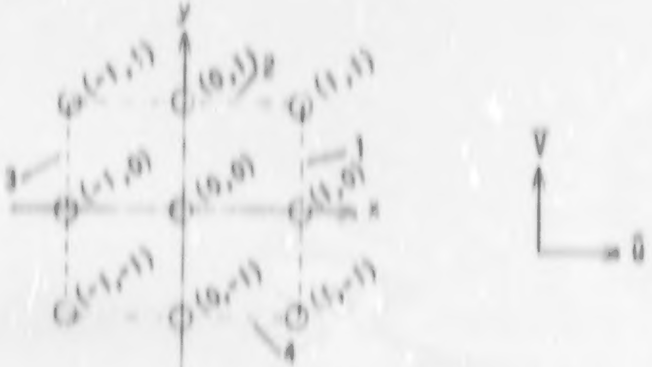
$$\overline{R} = \overline{\frac{\partial S}{\partial t}} + \frac{1}{V}\int_V \nabla \cdot [K\nabla S - S\vec{V}]\,dV = \overline{\frac{\partial S}{\partial t}} + \frac{1}{V}\int_A [K\nabla S - S\vec{V}]\,dA$$

BY GREEN'S THEOREM

ASSUME ALSO THAT S AND $\vec{V}$ ARE INVARIANT WITH DEPTH

$$\overline{R} = \overline{\frac{\partial S}{\partial t}} + \frac{1}{\ell^2}\left\{\pm\int_{1,3}\left[K\frac{\partial S}{\partial x} - S\hat{u}\right]dy \pm \int_{2,4}\left[K\frac{\partial S}{\partial y} - S\hat{v}\right]dx\right\}$$

FOR THE INTEGRATION FORMAT



USING EITHER PRISMOIDAL (SIMPSON'S) RULE $\left(\frac{1}{6}(1,4,1)\right)$ OR THE TRAPEZOIDAL RULE $\left(\frac{1}{4}(1,2,1)\right)$.

Figure 10. Rationale for integrating fluxes over the grid

Table 1. ANOV results of nutrient uptake rate data (t-statistic/n/% of confidence in discriminating between the pair of habitats--see text). Conditions: 1 = trapezoidal integration; 2 = eddy diffusivity $K = 10^5$ cm^2/sec; 3 = uniform current field calculated from individual flow vectors.

Nutrient	Sand/Reef	Reef/Sewage	Sand/Sewage
O_2	1.87/6/90%	<70%	4.06/5/99%
NO_3	<70%	2.15/11/95%	1.31/5/75%
PO_4	<70%	1.73/11/90%	1.13/5/70%

Table 2. Summary of chemical data, Lake Tunis grids, 1975

Site	Concentration µg at/ℓ	Rate of solution ng at/ℓ/s		N/P mole ratios		
		$K=10^3$ cm^2/s	$K=10^5$ cm^2/s	Conc.	Rate[a] $K=10^3$ cm^2/s	$K=10^5$ cm^2/s
Sand				0.45	2.71	−0.12
O_2	936	0.53	−23.2[b]			
NO_3	0.33	− 0.0026	− 0.012			
PO_4	2.11	0.0014	0.090			
Reef				25.23[c]	28.75	−7.61
O_2	1043	16.03	22.6[b]			
NO_3	1.38	− 0.0082	0.163			
PO_4	2.48	0.0047	0.067			
Sewage				4.80	−3.13	3.61
O_2	2073[d]	13.27	23.1			
NO_3	3.79	0.031	− 0.379			
PO_4	4.95	− 0.075	− 0.564			

[a] Theoretical = 16 (Redfield-Richards).

[b] Maximum expected for fertile region is 1 ng at/ℓ/s; for kelp bed it is 25 ng at/ℓ/s.

[c] Average without November data is 0.55.

[d] Possibly high from Fe^{2+} contamination. Data on 11 July showed an average of 172 µg at O_2/ℓ. Saturated level at 25 C and 20 ppt Cl is 450 µg at O_2/ℓ.

Although most nutrient concentrations and rates measured in Lake Tunis are reasonable, a number of unexplained relationships exist. Redfield-Richards mole ratios of O_2:NO_3:PO_4 uptake by phytoplankton in open ocean and anoxic, trapped waters is ~276:16:1. As plant matter is decomposed by bacteria, changes in concentration of these nutrients in the water occur approximately with the same ratios, though nitrates are usually liberated at a lower rate than phosphates, and ammonia is preferentially absorbed over nitrate. Lake Tunis data differ from this idealized model in several respects. First, the average mole ratio of N/P uptake rates is much less than 16 in all habitats. In the two unpolluted areas, in fact, the average ratios are negative and indicate that one nutrient is lost to the water while the other is simultaneously absorbed. Second, the sewer effluent during spring shows the highest oxygen concentrations even though observations of methane and hydrogen sulfide indicate an incompatibility with oxygen. Here also the average rate of oxygen absorption by the water was found to be large while simultaneously NO_3 and PO_4 were being removed. These measurements indicate a high rate of photosynthesis. Even though phytoplankton mixed with high nutrient-laden effluent could take up nutrients and liberate oxygen, the measured rates in Lake Tunis are over an order of magnitude higher than those observed under highly productive ocean conditions. The rate of oxygen release observed over the reefs from analyses over the 9-point grid is very close to that measured over kelp beds, but an apparent regeneration rate for NO_3 and PO_4 overshadows the uptake rate expected to accompany oxygen release. Finally, the usually high rate of oxygen removal from water over the sandy habitat is unrealistic. For these reasons, our present understanding of nutrient uptake (or release) for biota in a wind-driven, shallow eutrophied lake is incomplete. Assuming the role of ammonia is minor, the results indicate a much tighter network of simultaneous sampling and flow measurements is required. It is expected that experiments underway in regions of the lake isolated by plastic boxes will clarify the problem of highly variable rate measurements.

Average concentrations shown in Table 2 indicate significant differences in nutrients between habitats. In the sandy region, for example, phosphate levels are less than one-half those in the polluted region, and the nitrate levels are less than one-tenth. Corresponding nutrient concentrations over reefs are intermediate between the other habitats and show the highest oxygen content (200% of saturation).

The exchange of oxygen with sediment was measured in the laboratory by monitoring with an oxygen electrode in water over freshly dug surface sediment. In 13 hr, the oxygen concentration decreased linearly from saturation to 1.75 mg/liter. Nitrate was found to go to zero and phosphate increased over the duration of the experiment. These observations indicate a possible mechanism for establishing the N/P concentration ratios that were observed in the water during grid studies (Table 2). Organic phosphate is mineralized by bacteria and nitrate is reduced to ammonia within the sediment. In this manner, sediment provides a nitrate sink and a phosphate source with respect to lake water. Rates of ammonia released by polychaetes measured at the College of William and Mary (Dr. Charlotte Mangum's unpublished data) indicate that a dense population of such animals would account for rates of 1 ng-at/ℓ/sec. This is in reasonable agreement with the nitrate uptake and release rates in Table 2.

ACKNOWLEDGMENTS

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AN OVERVIEW ON THE INSTITUTE OF OCEANOGRAPHY AND FISHERIES, ACADEMY OF SCIENTIFIC RESEARCH AND TECHNOLOGY, ARAB REPUBLIC OF EGYPT

Aboul Fotough Abdel-Latif Mahmoud, Director General
Institute of Oceanography and Fisheries
Cairo, Egypt

INTRODUCTION

The Academy of Scientific Research and Technology in Egypt is the main governmental body concerned with the aquatic environment. To it belong the Atomic Energy Establishment, National Research Centre and such specialized research institutes as National Institute of Standards, Institute of Oceanography and Fisheries, Observations, Institute of Bilharzia, and Institute of Petroleum, besides three scientific services bodies, namely, National Information and Documentation Centre, Scientific Instruments Centre, and Science Museum. The Academy also has a number of specialized councils composed of senior scientists and high level governmental department representatives. Among these councils may be mentioned the Council of Researches of Animal and Fisheries Resources and the Council of Environmental Research. Projects agreed upon by a council could be funded by the Academy and operated by various institutions in the country within or outside the general framework of the Academy.

BACKGROUND

Egyptian interest in marine sciences dates to the 1930's when the Alexandria Institute of Hydrobiology (Fisheries Directorate, Ministry of Agriculture) and Marine Biological Station of Al-Ghardaqa Red Sea (University of Cairo) were established. Even then Egypt participated in an oceanographic expedition by contributing the vessel *Mabahiss* and Egyptian scientists in the John Murray Expedition to the Indian Ocean (1933-34). Furthermore, university graduates specializing in oceanography have been studying in the Department of Oceanography, Alexandria University, since 1948. Special courses in marine biology, hydrobiology and ichthyology are included in the curriculum of the Zoology Departments of Ain Shams and Cairo Universities for undergraduates.

With creation of the Ministry of Scientific Research (1962), the different governmental institutes (viz. the Marine Biological Station of Al-Ghardaqa and the Hydrobiology Institute of Alexandria) were combined as the Institute of Oceanography and Fisheries, Academy of Scientific Research and Technology.

OBJECTIVES

1. Undertaking of scientific, applied and economic research for conservation of fisheries resources and development.

2. Discovery of new fishing regions and the best suitable fishing gear.

3. Research on optimal methods of fish utilisation.

4. Establishment of fish farms under governmental or private auspices.

5. Supervision and cooperation in fish statistics work.

6. Technical advice to those concerned and governmental bodies for laws and regulations on fish management.

7. Cooperation in preparing governmental plans for fisheries development.

8. Geological, geomorphological, and similar surveys to clarify ways and means of protecting shores from erosion.

9. Training program for research and technical assistants.

DIVISIONS

1. Mediterranean Sea Branch: Headquarters at Alexandria, three stations at Matari, Baltim and Max. Plan includes establishing two new stations at Salloum and Port Said.

2. Red Sea Branch: Headquarters at Al-Ghardaqa, three stations at Al-Ghardaqa, Suez and Port Tawfik. Plans include extending the activity southward and a new station to be established in the southern Egyptian coast of the Red Sea.

3. Inland-Water Fisheries and Fish Culture Branch: Headquarters in Cairo, research stations at Nile Barrages near Cairo, Serow, Lake Quarun and Lake Nasser (Aswan). A station is planned at Assiout, halfway between Cairo and Aswan.

4. Shore-Protection Research Branch: Headquarters at Alexandria, two stations at Abu Kir and Ras El Bar.

DEPARTMENTS

For marine and fresh-water environments, 11 departments (with different units) serve the first three branches without regard to location, as follows: Departments of Physical and Geological Oceanography, Chemical Oceanography, Ichthyology, Fisheries Biology, Hydrobiology, Marine Invertebrates, Fish Culture, Statistics and Population Dynamics, Limnology, Artificial Breeding and Acclimatization, and Biochemistry; National Oceanographic Data Centre, and National Marine Biological Reference Centre (the latter two to be ranked at branch level in the future.

For shore protection there are the Departments of Geology, Physical Oceanography, Hydrodynamics, Shore Constructions, Data Processing, and Model Testing.

RESEARCH TRENDS

The Mediterranean Sea Branch conducts research programs aimed at a detailed survey of the A.R.E. waters in the Mediterranean and neighboring lakes (Edku, Mariut, Burullos and Manzalah). Research includes oceanographic observations both physical and chemical, marine geology, and hydrobiology as well as fisheries biology of economically important species.

The Inland Fisheries and Fish Culture Branch is carrying out research to increase commercial fish population in artificial ponds, natural and man-made lakes, and inland running water. In this respect, a successful program has been carried out in Lake Quarun through improving handling methods, transport and acclimatization of such fish fry as *Mugil* sp. and *Sparus auratus*. Studies include artificial and natural breeding of some inland fishes. Experiments are designed for high yield of fishes/ha through artificial feeding, stocking with different species, and varying stocking rates.

The Red Sea Branch is concerned with research for the Red Sea region including the Gulf of Suez. Emphases are on ecology of the coral reefs and exchange of fauna between the Red Sea and the Mediterranean through the Suez Canal. Taxonomy, ecology and development of invertebrates (particularly crustaceans, molluscs, echinoderms and polychaetes) are also some of the concerns for future benefit. Since the Port Tawfik and Suez stations were badly affected in the Middle East wars, references and apparatus are badly needed for future work.

The Shore-Protection Research Branch is mainly concerned with ways and means of protection of Mediterranean shores as well as protecting the River Nile from erosion as the flood silt is no longer carried there and sedimented since completion of the Aswan High Dam.

RESEARCH STAFF

Personnel include 7 professors, 11 assistant professors, 20 researchers, 30 research assistants and 120 specialists. The first three categories are at the Ph.D. level and the latter two are working toward the Master's or doctorate.

PUBLICATIONS

The Marine Biological Station has published "Publications of the Marine Biological Station, Al Ghardaqa" (14 volumes), the Hydrobiology Institute has issued "Notes and Memoirs (about 60), and with combination of the different research units, a new annual journal entitled "Bulletin of the Institute of Oceanography and Fisheries" (5 volumes to date) is published.

POLLUTION PROBLEMS

This will be covered in detail by Professor S. El-Wakeel, Director of the Alexandria Branch. Generally, work on pollution of the marine environment has only recently begun although the freshwater environment has been dealt with for some time. Through contacts with specialized agencies, cooperation will proceed in regard to the Mediterranean. The River Nile and Lake Nasser project is supported by EPA-Ford Foundation and University of Michigan. The various Red Sea area countries are aware of pollution but at the second conference of Jedda, a resolution was made to pinpoint oil pollution problems first. The Gulf of Suez is the most suitable location for the required monitoring and studies on effects of oil on marine organisms. In regard to heavy metals, mercury is recommended as the starting point in our institute. Extensive beds of *Mytilus* are found in the area.

CONCLUSION

To varying degrees, developing countries are confronted with food problems because of rising birth rate and shortage of resources. Exploitation of these resources has not reached the optimal level, as trained personnel and basic research funds are in short supply. It is thus necessary to define the resources, how they could be developed and what future constraints will be.

In light of the limitations mentioned, it is necessary for a developing country to continue evaluation of all types of pollutants. Defining the important pollutants is the only way to achieve positive results in the shortest time. The importance of pollution in terms of contamination of seafood products, affecting health and food commodity availability, cannot be over-emphasized.

Support of pollution-abatement activities can be achieved in many ways, including funding for experts, training grants, equipment, etc. Nevertheless, such support must be geared to the specific technological and economic situation of the particular country. In many instances, shortages of trained personnel and problems in equipment maintenance may necessitate use of less complicated analytical apparatus, but functionally dependable for specific operations.

Further efforts should be directed toward development (perhaps by the U.S. EPA) of specialty manuals in various fields of pollution. Certainly, analytical technique manuals are needed. The impact of pollution on natural resources and public health needs continued emphasis along with an updating of the problem and its ramifications.

Legislation and the enactment of pollution-abatement laws, especially their enforcement, poses real problems in many developing countries. Proper understanding of the problem and its impact is necessary for effective implementation of any such legislation. An educational program, using an array of audio-visual aids, films, pamphlets, etc., is necessary to thoroughly familiarize the population in question with the implication of pollution in their social and economic systems. Such education is only effective if it is geared to the literacy level of the people it endeavors to reach.

Lastly, all aspects of pollution must be considered, including that of the microorganisms involved as well as the particular pollutant. In many instances, the latter may stimulate development of a particular organism which may pose significant disease-related problems. Certainly, symposia of this type, along with proper dissemination of data and methodology standards, are of significance, both for industrialized and developing countries.

GLOBAL MONITORING OF MARINE POLLUTANTS

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There are several compelling reasons to initiate a continuing and systematic surveillance of already defined pollutants in coastal marine waters. First, the present exposure levels to marine organisms can be used in principle by ecologists to ascertain whether any organisms or communities of organisms are threatened. Second, environmental concentrations allow an assessment of dangers to public health through the consumption of seafoods. Third, present levels allow predictions of future levels. With knowledge of present and past environmental releases of the pollutant in question and with an estimate of future leakages based upon production and use, data models for pollutant dispersion about the environment can be formulated and future levels may be foretold. Such information is vital to those responsible for management of marine resources. Where predicted levels are unacceptable on the bases of possible environmental impact, restrictions upon releases can then be imposed.

The many proposed large-scale monitoring programs are usually characterized by their vastness and complexity which lead to their doom as fantasies on paper. Inputs from biologists, chemists, physicists, geologists, meteorologists and engineers have indicated a need for measurements which would tax the facilities of the marine science community. While such documents pass for review from one agency to another, the coastal waters continue to receive industrial and domestic wastes and there is no systematic attempt to measure the exposure levels of already identified major pollutants in various parts of the ocean.

There are four collectives of pollutants that may jeopardize continued use of marine resources: artificial radionuclides (the transuranics Pu-238, Pu-239+240, and Am-241 and Cs-137); petroleum hydrocarbons; chlorinated hydrocarbons (DDT residues, PCBs, chlorinated styrenes, hexachlorobenzene, and other insecticides and their degradation products); and heavy metals (lead, cadmium, mercury, selenium, zinc, silver and copper). The first three sets of pollutants cited are extremely difficult to measure in low concentrations. Talented analysts using highly sophisticated techniques are necessary to achieve reliable measurements of concentrations of these substances in materials from the marine environment. For some, i.e., the halogenated hydrocarbons and petroleum hydrocarbons, measurements in sea water are so taxing, due to the extremely low concentrations of the pollutants, that only a few dozen reliable measurements have been performed. As a consequence, sea water assays may not be the most reasonable way to ascertain marine concentrations of these sets of pollutants. Sentinel organisms offer a realizable approach to the measurement of pollutant levels.

Mussels and barnacles are especially attractive as sentinel organisms for measurement of the exposure levels of these pollutants. The mussel *Mytilus edulis* has been extensively studied both experimentally and ecologically with respect to its ability to record pollutant levels. Plutonium exposure levels appear to be recorded in both the shell and in the soft parts (Noshkin et al., 1973). Molluscs are well known concentrators of heavy metals (Lowman et al., 1971). The mussels *Mytilus edulis* and *Mytilus californianus*, collected in the intertidal zones along the Pacific coast from northern California to Baja California, maintained lead burdens in their soft and hard parts that reflected human activity in the adjacent lands (Chow et al., 1976). Where there was a dense population of people and an associated high usage of automobiles with leaded gasolines, the coastal mussel population maintained high lead concentrations. In areas of sparse habitation, the lead levels were several orders of magnitude less. The soft parts of the mussels contained from 0.37 to 43 ppm of lead on a dry weight basis.

Mussels have been used already in a regional monitoring program of halogenated hydrocarbons and mercury (Holden, 1973), and are valuable as sentinels for hydrocarbon pollution. They rapidly take up both saturates and aromatics from their environs and store them with little metabolic breakdown (Lee et al., 1972). *Mytilus edulis* responds quickly to the total hydrocarbon burden of its environment through tissue uptake, and also rapidly releases such pollutants upon exposure to clean waters (Di-Salvo et al., 1975). The organism is a bay and sheltered coastal species and will monitor environmental levels well in such localities. It is a filter feeder and its viscera are compact and easily separable from the shell. Furthermore, the species is widespread in the northern hemisphere and there should be no problem about introducing it to places where it may not already occur. Transplantation to areas where the organism is not indigenous has been carried out successfully in an area near a sewer outfall off the coast of southern California (David Young, SCCWRP, personal communication, 1975). The mussels were suspended in nylon mesh bags from the surface to the bottom (35 m) on a taut wire.

A second group of organisms which appears worthy as sentinel organisms encompasses the goose barnacles (*Lepas*). Unlike the mussel it is an oceanic species, easily caught in neuston nets. Although the 20 or 30 odd species that make up the genus are sometimes difficult to identify, the species inhabiting one region should be relatively unchanging with time. The goose barnacle is quite cosmopolitan, being found in nearly all coastal waters. Less work has been carried out on its body burden of pollutants than for the mussel *Mytilus*, yet it is now attracting increased attention as a sentinel organism.

With this background, we can proceed to the protocols of initiating a monitoring system based upon the most substantial existing information. On a regional basis, we have already planned a mussel watch for the coastal waters of the United States under the sponsorship of the Environmental Protection Agency. Over 100 stations will be visited during the period 1976-1977 for this program. An extension to global coverage can follow a similar pattern. The costs and scope of the program will be continually assessed on the basis of economy and as to whether the gathered information provides those responsible for the management of coastal areas with a substantial appraisal of the degrees of pollution and trends in pollutant levels.

PARTICIPATING LABORATORIES

1. At least two laboratories, in different areas, will be chosen for each collective of pollutants. Following the initiation of the program, each laboratory will be responsible for the analyses of approximately 50 samples for the collection of pollutants within their domain, and will be responsible for intercalibration exercises on the pollutants being analyzed. Results on the 50 samples are to be available within 9 months after their receipt. The laboratories also will analyze existing Standard Reference Materials (SRMs) for their pollutant levels or prepare reference standards where SRMs are not available from such institutions as the Bureau of Standards or the International Atomic Energy Agency Laboratory at Monaco.

2. Since the highest quality results are being sought, the identification of participating laboratories has been sought from some of the leaders in the field of marine pollution.

SELECTION OF POLLUTANT SPECIES TO BE MEASURED

1. The polluting species to be measured include those substances that have been shown to jeopardize life processes in the ocean or that are similar to chemicals that have been associated with undesirable impacts upon living systems. These species are cited specifically in the Appendix and include: heavy metals (lead, cadmium, mercury, selenium, zinc, silver and copper as total concentrations); chlorinated hydrocarbons (DDT residues, polychlorinated biphenyls, hexachlorobenzene, dieldrin, endrin, heptachlor, benzene hexachloride, cis- and trans-chlordane and insecticidal derivatives oxychlordane and heptachlor epoxide; artificial radioactive nuclides (plutonium-238, plutonium-239+240, americium-241 and cesium-137); and petroleum hydrocarbons (to include measures of the concentrations of alkanes, cycloalkanes and aromatics including 2-, 3-, 4- and 5-ring polynuclear condensed species).

2. Certain characteristics of the organisms and of the chemicals must be taken into account during the sampling program. For example, mussels apparently mobilize and release a large fraction of their stored contaminants. A reasonable tactic then would be to collect the organisms before spawning or at a period of 5 or 6 months after spawning, presuming there is a pattern of annual spawning. For chemicals such as petroleum that may have highly variable concentrations in the sea waters, sampling may have to be more frequent. Lifetime exposures to pollutants may be found in the hard parts with such pollutants as the transuranics and lead. Along this line, size classes must be considered an important parameter in the sampling program.

3. Chemical species will be added to the list as they are identified by laboratory and/or field studies. Substances for which levels in organisms from polluted areas are indistinguishable from those of adjacent unpolluted areas will be removed from analysis, if this observation holds at all of the stations. Clearly, stations adjacent to those cited above as primary stations can serve to give more detail to the sampling program. Still, limitations upon the number of stations must be made to avoid too many samples or obligations for servicing stations.

Initially, sampling intervals might be twice annually. The number of individual organisms to be assayed appears to be at least 50 (for DDE analyses, a change in concentration of twice the standard deviation from replicate samples could be detected if 50 individuals were assayed for each of the various sets of pollutants). Additional samples should be maintained in a freezer library for reference materials in future baseline studies or for subsequently identified pollutants.

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APPENDIX

CHARACTERISTICS OF MARINE POLLUTANTS

Petroleum

Species to be Analyzed: Alkanes, cycloalkanes and aromatic hydrocarbons by column, thin layer and/or liquid chromatography.

Analysis of the isolated hydrocarbon fractions by gas chromatography or high pressure liquid chromatography to determine where possible individual hydrocarbon concentrations and the complexity and molecular weight range of the mixture of hydrocarbons.

Extensive separation of and then quantitation of 2-, 3-, 4- and 5-ring polynuclear aromatic hydrocarbons.

Sample size: 1000 g

Heavy Metals

Species to be Measured: Lead, cadmium, mercury, selenium, zinc, silver, copper.

Techniques: Atomic Absorption

Sample size: 100 g per analysis

Notes:

1. The presence of inorganic sedimentary phases can be measured through analyses of manganese, iron and aluminum. These substances could be introduced into the program at a very small increment in cost.
2. Isotope shift--Zeeman Effect Atomic Absorption techniques appear to offer significant advances in sensitivity and precision over conventional techniques for Hg and perhaps for other elements as well (Pb, Se, Cd, Zn).

Chlorinated Hydrocarbons

Species to be Measured: DDT residues consisting primarily of p, p' DDT, p, p' DDE and p, p' DDD, and to a lesser extent of o,p' DDT, o,p' DDD and p, p' DDMU

Polychlorinated biphenyls

Chlorinated styrenes

Hexachlorbenzene

The insecticides dieldrin, endrin, heptachlor, isomers of benzene hexachloride, cis-chlordane, trans-chlordane

The insecticidal derivatives oxychlordane and heptachlor epoxide

Techniques: With the exception of the chlorinated styrenes, these compounds can be identified with reasonable certainty by gas chromatography. Early eluting peaks, such as HCB, might require gas chromatography/mass spectrometry for identification in some samples, or at least the application of a confirmatory procedure.

Sample size: 1000-2000 g

Artificial Radionuclides

Species to be Measured: Plutonium-238 (alpha emitter); Plutonium-239+240 (alpha emitters); Americium-241 (alpha emitter); Cesium-137 (gamma emitter)

Techniques: Alpha and gamma spectrometry

Sample size: 100-1000 g per analysis

Notes:

1. On the basis of present data, the hard parts (exoskeleton) of the mussel record environmental levels somewhat more satisfactorily than the soft parts.
2. Other gamma-emitting nuclides could be introduced into the program at a very small increment in cost.

SUMMARY

The participants in the International Symposium on Marine Pollution Research expressed concern about the continual and increasing pollution of the marine environment, in particular the potential adverse effect of marine pollution on the production of protein from the sea. Participants discussed several broad issues relating to international marine pollution and some specific areas of potential international cooperation. Broad issues and specific areas of potential research are listed in order of discussions, not necessarily in order of priority.

Broad Issues

- Identification of Pollution Problems--Each country must identify and prioritize marine pollution problems within their boundaries, only then can international problems be discussed and prioritized.
- Training and Technology Transfer--Training of non-professionals and professionals in the field of marine pollution must be accomplished on a worldwide basis. Training also can be accomplished through the transfer of technical information from one country to another. This can be accomplished through communications: individual to individual, workshops with scientific personnel from many countries, seminars and other technology transfer methods.
- Monitoring--Monitoring should be conducted only with a clear and concise purpose for the use of the monitoring data and a knowledge of the mechanisms in which the monitored pollutants were identified and quantitated.
- Impact on Biological Systems--Criteria must be developed for determining the impact of pollutants on biological systems.
- Water Quality Criteria--Quantitative and qualitative information has been developed at national and international levels on water quality criteria for ocean and coastal waters. This information should be made available to all interested countries and could be used as a starting point for countries who have not yet developed such criteria.
- Education--The importance and necessity of scientific education must be emphasized. It is particularly important to educate laymen, both government authorities and the public who may not have adequate technical backgrounds to understand the complexities of marine pollution and its impact on global systems.

Communication of Techniques--This is a special aspect of technology transfer that should be stressed in relation to the compilation of methods manuals for such items as (a) sampling, (b) chemical analysis, and (c) bioassays so that data collected from different nations can be compared.

Specific Issues

Participants highlighted briefly specific problems or issues applicable to their countries that also would be of global interest, for example:

- The effects of urban development, mercury and petrochemicals on the marine environment.
- The effect of natural siltation and petrochemicals on shrimp and other marine life.
- Mass-balance equations dealing with the movement of pollutants from air masses to the ocean including knowledge of variations in concentration of pollutants with space and time.
- The biogeochemistry of mercury and petroleum as these pollutants move in rather large "watershed areas" into the marine environment.

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